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AN EVALUATION OF TIME STUDY RATINGS OF A SYNTHETIC TASK

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ABSTRACT

Rating is a process in which we relate observed performance to a designated concept of standard. This process is usually carried out to determine the "standard time". Performing the job in the standard time is called "standard performance".

There are two major methods of rating,

(1) methods using a mathematical formula,

(2) methods using judgement.

The mathematical formula methods are not considered as being accurate and are not in general use. Industry largely makes use of those methods involving judgement on the part of the rater.

Time study engineers in industry today have been on the job various lengths of time; have received their time study education from various sources, and utilize different concepts of "standard performance". It is believed that their accuracy in rating is affected by these and other factors such as area of employment, size of plant, as reflected in number of employees, and size of city in which plant is located. The objective of this thesis was to determine if any or all of these factors affect the accuracy and consistency of the ratings made by a typical group of time study engineers from the Mid-West region. This was accomplished by analyzing the ratings of job films in accordance with the following breakdowns:

1. Entire group.
2. Area.
3. Experience.
4. Initial source of time study training.
5. Concept of "standard performance".
6. Size of plant.
7. Size of city in which plant is located.

With the engineers assembled in a room, films of an operator performing a synthetic task were projected. The job was a simple laboratory operation, representative of light factory work. The films were divided into 12 loops with the operator working at a different pace in each loop. Loops were projected in a random order of pace. Engineers were instructed to rate by cycle and to employ any method of rating that they desired. Method of performing the job was stipulated to be correct. In order to place all ratings on a mutually comparable basis and to simplify the mathematical problem, Rating Conversion Scales were used by each man to convert his raw rating to that figure he would have assigned had he assumed 130 to be the maximum numerical value he would expect of the typical operator in his plant.

Conclusions.

An analysis of the results of a group of typical time study engineers when rating job films leads to the following conclusions:

8. Size of city. Size of city in which the plant is located apparently has little or no bearing on the raters' accuracy.

9. Consistency followed by the same direction as accuracy in all cases. It was, however, slightly higher. This was to be expected from the manner in which the data were handled.

This analysis suggests that when rating a job film we can probably expect of time study engineers, in terms of the percentage of personnel within limits indicated, the following degrees of accuracy:

±5% level: more than one third---38%.
±7½% level: almost one half-------48%.
±10% level: almost two thirds-----62%.
±20% level: the great majority----86%.

AN EVALUATION OF TIME STUDY RATINGS OF A SYNTHETIC TASK

INTRODUCTION

"Motion and time study refers to the analysis of the work and time necessary to do a certain job".[1] To find the time necessary we usually resort to a stop watch time study. A stop watch time study is accomplished by observing an operator performing the task and recording the time obtained. However, we note that if we should time another operator performing identically the same job, in the same manner, we very probably would obtain a different time of accomplishment. And if we studied a third operator we might get a third value of time. The question now arises, "which one of these workers is performing the task in the correct amount of time"? The answer to this question is required to establish a "standard time" for the job in question. Performing the job in the standard time is called "standard performance".

One definition of standard time given by Mundel[2] is, "the time necessary to do a certain job, defined as to method and conditions surrounding the work, by a operator physically fit for the job as the typical operator who could be expected on the job, possessing sufficient skill to do

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1 M. E. Mundel, Systematic Motion and Time Study, p. 3, Prentice-Hall, Inc., New York, 1947.

2 Ibid., p. 147.

the job properly, adapted to the job, and working at a pace 100/130 of the maximum he could maintain for the working day without harmful physical effects". But with all of these conditions understood and defined, it is still necessary to determine what relationship the performance of the operator observed bears to the pace defined as standard. The process of relating observed performance to a designated standard is called "rating", and further discussion will be confined to this subject.

There are two major methods of rating,

(1) methods using a mathematical formula,

(2) methods using judgement.

  (a) Multiple factor systems,

  (b) single factor systems.

Because of the great number of variables affecting the operators time the mathematical formula methods are not considered as being accurate, are not in general use, and will not be considered here.

An example of the judgement method is the "effort" rating plan. This plan involves two steps,

(1) judge the difficulty of the job and imagine a concept of reasonable performance,

(2) compares what he sees to this concept.

To carry out this method the time study man should be familiar with the visible appearance of the steps in the range of effort, as reflected in pace, on each type of job he ob-

serves.[3] In a plant with a variety of jobs this is not always feasible.

Now judgement must involve the determination of the effect of the operator's skill, aptitude, and effort on his performance. The system advanced by Mundel[4] accomplishes the above and entails the following steps on the part of the rater,

(1) compares the workers pace to a fixed concept of speed,

(2) adjusts the observed value for difficulty of the job.

It becomes obvious that a standard pace must be defined. The standard pace may be a man walking on a level at 3 miles per hour. Also it could be a person dealing a deck of cards into 4 equal stacks in one half of a minute.[5] It is evident some value or representation of pace must be made in order that judgement of pace be possible and effective. A physical embodiment of this designated pace could be a film of an operator walking or dealing cards at the respective rates indicated above. Some time study men have their own concept of standard performance and some utilize a film as previously mentioned. When using the Presgrave [5] system a different concept of the standard pace for each job is required.

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[3] Ibid., p. 157.

[4] Mundel, op. cit., p. 157.

[5] Ralph Presgrave, Dynamics of Time Study, 2nd ed., p. 154, McGraw Hill Book Co., Inc., New York, 1945.

Rating may be expressed as points per hour[6] or as a percentage figure. Percentage numbers are more widely used and will be employed in this thesis. There are various percentage systems in use but the following will be employed here: the maximum performance that could be expected of the typical worker, for the entire working day, without harmful physical effects will be 130 and standard performance will be 100/130 of this value.

To adjust for difficulty of performance on different jobs, tables are prepared with certain allowances for adjustment purposes.

Time study engineers in industry today have been on the job various lengths of time; have received their time study education from various sources, and utilize different concepts of "standard performance". It is believed that their accuracy in rating is affected by these and other factors such as area of employment, size of plant, size of city in which the plant is located.

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[6] Ralph M. Barnes, Motion and Time Study, 3rd ed., p. 353, John Wiley & Sons, Inc., New York, 1949.

OBJECT

The object of this thesis is to determine if any or all of these aforementioned factors affect the accuracy and consistency of ratings made by typical group of time study engineers from the Mid-West region. This object will be investigated by analyzing the ratings of job films in accordance with the following breakdowns:

1. Entire group.
2. Area.
   - a. Northern Mid-West, less Michigan.
   - b. Central Mid-West.
   - c. Southern Mid-West.
   - d. Michigan.
3. Experience.
   - a. 0-6 months.
   - b. 6 months - 2 years.
   - c. 2-4 years.
   - d. Over 4 years.
4. Initial source of time study training.
   - a. College.
   - b. Company.
5. Concept of "standard performance".
   - a. Rater uses own concept.
   - b. Rater uses a film or some other embodiment.
6. Size of plant, (number of employees).
   - a. 0-101 men.
   - b. 101-1000 men.

c. Over 1000 men.

7. Size of city in which plant is located.

    a. Under 5000.

    b. 5000-10000.

    c. 10000-25000.

    d. 25000-50000.

    e. 50000-100000.

    f. Over 100000.

PROCEDURE-PART A

In order to carry out the objectives of this thesis it was necessary to have a typical group of time study engineers rate a task or a number of tasks. To obtain this data Industrial Engineers from various firms located in Indiana, Illinois, Michigan, Ohio, and Wisconsin were invited to attend a "work session" at Purdue University on the 15th of March, 1950.

Data could have been obtained by having the raters view either a film of an operator performing a task or view an actual operator. For various reasons a film was chosen rather than an operator. Some of these reasons are:

1. A film was already available thus obviating the necessity of training an operator.

2. A film is more convenient as it can be viewed by a much larger group than could an operator working at a task.

3. Method and skill can be maintained more consistently and accurately by means of a film since many operators are distracted when performing in the presence of an audience.

4. It was shown by Margolin[7] that time study engineers rate more accurately and consistently from a job film than from an operator.

The film selected consisted of an operator performing a simple task, a job description of which is appended. The

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[7] Louis Margolin, "A Comparison of Two Methods of Presentation For Time Study Ratings", Unpublished Masters Thesis, Purdue University, 1948.

film was prepared in 1949 under the supervision of Lehrer.[8] It was divided into 26 parts in which the operator performed at a different pace in each part. The film had been carefully edited to eliminate any fumbles, false movements or any other irregularities. Considerations involved in the selection of this film were:

1. It involves sharp clear motions and elements.

2. Includes motions of the hands and arms that are typical of light factory work.

Twelve loops were prepared from the film. They were carefully checked to insure that the ratio between the elements of a given loop in each cycle were the same. Loops were arranged in a random order of pace for projection purposes.

It being realized that different time study men utilize different numerical maximum percentage values as expectable of the typical worker, rating conversion scales were prepared for their use. In this manner they could convert their raw rating to the one in which 130 represents the typical maximum.

Two IBM mark sensing cards were prepared for issuance to each man. These cards were punched with identifying data for each man. It was arranged that each man would then enter his "converted rating" directly on the IBM cards.

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[8] R. N. Lehrer, "Development and Evaluation of a Pace Scale for Time Study Rating", Unpublished Doctors Thesis, Purdue University, 1949.

PROCEDURE-PART B

The engineers assembled in the lecture room of the Electrical Engineering building and after a greeting by Dr. M. E. Mundel, Professor of Industrial Engineering, General Engineering Department, Purdue University, a questionnaire was handed out to each man. This questionnaire was for the purpose of collecting information for the thesis of Borrus.[9] It further served the purpose of procuring the necessary information such as area, experience, etc., of each man for this thesis.

On completion of the questionnaire the IBM mark sensing cards, special pencils, rating conversion scales, were issued to each man. Instructions for their use was given.

Engineers were requested to rate by cycle, using their own system of rating. Method of the job was stipulated to be correct. They were further reminded to use the rating conversion scales in order that all ratings would be on a mutually comparable basis.

A loop was projected for a short time to familiarize each man with the method of the job. On completion of this showing the session began. Loops were projected at the same speed at which they were made. About 2 minutes were allowed for projection and about 1 minute for recording of ratings. This procedure was continued until all 12 paces were shown.

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[9] Bernard S. Borrus, "The Present State of Time Study", Unpublished Masters thesis, Purdue University, 1950.

PROCEDURE-PART C

After all 12 paces had been rated the IBM cards were delivered to the IBM Computing Laboratory where all necessary data were punched on the cards. The IBM Laboratory supplied the following information for each pace and for each category of breakdown:

1. Number of raters.
2. Totals of their scores.
3. All ratings made.
4. Number of raters with a specific score.

With this information, corrected values for each pace was determined. Mathematical procedure for determining this is contained in Appendix B. With the corrected value of each pace obtained, and the information from IBM, analyzation for accuracy was made by noting the number and percentage of raters within ±5%, ±7½%, ±10%, ±20% of the corrected values for each pace and for each category of breakdown.

To analyze for consistency, the same procedure was employed except the average of the raters' values was used as the measure about which the variation was appraised.

To arrive at conclusions the data were investigated by inspection and by the "analysis-of-variance" technique. The analysis-of-variance technique was employed at the ±5% and ±10% level of accuracy in all cases and at the ±20% in a few. Appendix B has a short discussion on the analysis-of-variance technique.

Raters' averages were plotted against the corrected values for each category of breakdown. A line, determined by the method of "least squares", was drawn through these points. This line indicated the points at which raters tended to depart from the ±5% and ±10% levels of accuracy. Appendix B contains a short discussion on the "least squares" method of fitting a curve through a set of points.

CONCLUSIONS

An analysis of the results of a group of typical time study engineers, when rating job films of various paces, leads to the following conclusions:

1. For all categories, a plot of the average of the ratings against the corrected ratings indicates a trend of the time study engineers to rate too low at the higher values and too high at the lower values.

2. The line best fitted, by mathematical means, to all points for the entire group, suggest the trend of this group, on the average, to be outside the +5% level at values below about 93; the +10% level at values below about 75; the -5% level at values greater than 165; the -10% level at values in excess of 220.

3. Area. The Michigan area had a comparatively low degree of accuracy, the analysis-of-variance test showed it to be significant, but since their amount of experience and familiarity with the method of rating a job film was not determined, and the sample was very small, their score is disregarded. Discounting the Michigan category, raters from various areas rated essentially the same. Therefore, the area in which the plant is located appears to have little or no relationship to accuracy.

4. Experience. Groups with 6 months or more experience rated about the same but with greater accuracy than those with less experience. Those in the 2-4 years category were

slightly higher than the rest. The analysis-of-variance test failed to indicate that the low score of the 0-6 months group was significant, but in view of the irregularity of their accuracy, as indicated by inspection of Table 7a, it is suggested that in general at least 6 months experience is required to make the qualified time study engineer but that accuracy then remains about the same with increased experience.

5. Education. The accuracy of the raters at the ±5% level is practically equal. The 1% difference in their accuracy is not significant. However, at the ±10% level those raters receiving their initial time study training from a company show a significantly, by analysis-of-variance test, greater accuracy. This suggests, at least for this group, at the higher level of accuracy, initial source of time study training does not affect accuracy. At a less rigid degree of accuracy, time study men receiving initial time study training from the company are more accurate than those receiving it from a school. This may not be true of those receiving modern training from either school or company.

6. Concept of Standard Performance. Raters using a film or some other embodiment of standard performance as common practice were superior to those using their own concept despite the fact that no film aid was used in this phase. The difference in accuracy was not significant at the ±5% level of accuracy but was definitely significant at the ±10% level.

It is therefore suggested that raters should use a film or some other embodiment of "standard performance", and this reinforces the last statement of conclusion 5.

7. Number of Employees. By inspection the raters in plants employing less than 101 men rated a little lower than those in larger plants. However, this difference is not significant. Therefore the size of plant as reflected in number of plant employees apparently has no effect on raters accuracy.

8. Size of city in which plant is located. Inspection reveals a wide difference in accuracy between a city of less than 5,000 people and a city of 5,000-10,000 people; the analysis-of-variance tests reveals this difference to be insignificant at the ±5% level of accuracy and barely significant at the ±10% level. It is therefore suggested that size of city, in which the plant is located, does not affect raters accuracy significantly.

9. Consistency followed by the same direction as accuracy in all cases. It was, however, slightly higher. This was to be expected from the method in which the data were handled.

10. This analysis suggests that when rating a job film we can probably expect time study engineers in terms of the percentage of personnel within limits indicated, to perform with the following degrees of accuracy:

±5% level: more than one third----38%.

±7½% level: almost one half--------48%.

±10% level: almost two thirds------62%.

±20% level: the great majority-----86%.

APPENDIX A

Table 1a

Breakdown: Tabulation of Numerical Results of all Categories.

Computed for Accuracy

	±5%		±7½%		±10%		±20%	
	No.	%	No.	%	No.	%	No.	%
Overall.	27	38	35	48	45	62	62	86
Northern Mid-West, Less Michigan.	7	37	11	53	12	61	17	85
Central Mid-West.	12	38	17	55	20	65	27	89
Southern Mid-West.	5	42	7	59	9	72	11	88
Michigan.	2	21	3	36	4	45	7	77
Experience,								
0-6 mos.	2	33	3	47	4	58	5	78
6 mos.-2 yrs.	7	42	9	53	10	64	14	86
2-4 yrs.	7	39	10	54	13	66	18	93
Over 4 yrs.	11	39	16	53	18	63	26	89
Education.								
College.	8	36	11	49	13	59	18	81
Company	16	38	24	56	28	66	39	87
Use own Concept of Standard Performance	20	37	28	51	34	62	49	87
Uses film or other embodiment of Standard Performance	7	44	9	61	11	75	15	98

Table 1b

Breakdown: Tabulation of Numerical Results of all Categories.

Computed for Consistency

	±5%		±7½%		±10%		±20%	
	No.	%	No.	%	No.	%	No.	%
Overall.	29	40	41	57	50	69	62	86
Northern Mid-West, Less Michigan.	8	39	11	52	13	66	17	86
Central Mid-West.	13	42	18	58	23	73	27	88
Southern Mid-West.	6	51	8	63	9	74	11	88
Michigan.	3	31	3	37	4	48	6	71
Experience,								
0-6 mos.	2	35	3	51	4	65	5	82
6 mos.-2 yrs.	6	40	9	57	11	66	14	87
2-4 yrs.	8	39	12	61	13	70	17	91
Over 4 yrs.	13	44	17	58	20	67	26	90
Education.								
College.	8	38	12	54	14	64	18	82
Company.	19	43	27	60	32	71	40	88
Use own Concept of Standard Performance	20	38	29	53	37	68	47	87
Uses film or other embodiment of Standard Performance.	8	56	11	72	13	84	15	98

Table 2a

Breakdown: Entire Group.

Number of Raters: 72

Evaluation for accuracy.

Corrected Ratings.	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
155	12	29	47	46	64	48	67	66	92
143	4	23	32	32	44	47	65	67	93
137	11	38	53	46	64	57	79	66	92
132	8	34	47	44	61	50	69	63	87
122	1	31	43	45	65	56	78	67	93
118	5	30	42	45	65	52	72	65	90
105	10	25	34	32	44	42	58	63	87
98	2	31	43	40	55	49	68	64	89
95	6	26	36	32	44	42	58	57	79
92	3	24	33	28	39	35	49	60	83
81	9	17	24	21	29	28	39	53	74
79	7	18	25	26	36	32	44	54	75
Average:		27	38%	35	48%	45	62%	62	86%

Table 2b

Breakdown: Entire Group

Number of Raters: 72

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
149	12	36	50	44	61	52	72	64	89
135	4	35	49	49	68	62	86	68	95
135	11	36	50	48	67	59	82	66	92
130	8	30	42	45	63	48	67	63	88
121	1	33	46	48	67	58	81	67	93
115	5	33	46	43	60	54	75	66	92
110	10	26	36	42	58	51	71	61	85
102	2	27	37	43	60	48	67	64	89
101	6	28	39	37	51	44	61	58	81
98	3	22	31	41	57	49	68	61	85
86	9	19	26	22	31	31	50	54	75
84	7	20	28	28	39	34	47	50	79
Average:		29	40%	41	57%	50	69%	62	86%

Table 3a

Breakdown: Area-Northern Mid-West, less Michigan.

Number of Raters: 20

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
152	12	5	25	12	60	12	60	19	95
140	4	8	40	12	60	13	65	18	90
134	11	9	45	12	60	17	85	18	90
129	8	9	45	12	60	14	70	17	85
119	1	16	80	17	85	18	90	20	100
115	5	10	50	14	70	15	75	18	90
102	10	4	20	5	25	7	35	17	85
96	2	7	35	13	65	13	65	19	95
93	6	8	40	9	45	9	45	16	80
90	3	6	30	10	50	11	55	17	85
79	9	4	20	6	30	9	45	13	65
77	7	3	15	6	30	10	50	14	70
Average:		7	37%	11	53%	12	61%	17	85%

Table 3b

Breakdown: Area-Northern Mid-West, less Michigan.

Number of Raters: 20

Evaluation for consistency.

Average Ratings.	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
147	12	6	30	8	40	11	55	19	95
132	4	14	70	16	80	18	90	19	95
134	11	8	40	11	55	13	65	18	90
127	8	8	40	12	60	14	70	17	85
120	1	15	75	16	80	18	90	20	100
113	5	11	55	13	65	15	75	18	90
106	10	4	20	8	40	10	50	17	85
101	2	7	35	11	55	16	80	19	95
100	6	5	25	7	35	14	70	15	75
94	3	9	45	10	50	13	65	18	90
80	9	4	20	7	35	9	45	14	70
79	7	4	20	7	35	9	45	14	70
Average:		8	39%	11	52%	13	66%	17	86%

Table 4a

Breakdown: Area-Central Mid-West.

Number of Raters: 31

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
150	12	19	61	20	65	23	74	30	97
139	4	12	39	17	55	21	68	30	97
133	11	17	55	27	87	28	90	30	97
128	8	13	42	18	58	27	87	29	94
118	1	13	42	23	74	27	87	29	94
114	5	15	48	20	65	25	81	31	100
102	10	8	26	15	48	16	52	25	81
95	2	15	48	19	61	21	68	25	81
93	6	9	29	13	42	14	45	26	84
90	3	8	26	14	45	15	48	26	84
79	9	5	16	9	29	11	36	23	74
76	7	6	19	9	29	14	45	25	81
Average:		12	38%	17	55%	20	65%	27	89%

Table 4b

Breakdown: Area-Central Mid-West.

Number of Raters: 31

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
143	12	13	42	18	58	27	87	29	94
131	4	14	45	22	71	29	94	31	100
129	11	18	58	24	78	27	87	31	100
126	8	12	39	20	65	26	84	29	94
119	1	13	42	22	71	27	87	29	94
111	5	13	42	20	65	23	74	30	97
107	10	12	39	17	55	24	78	28	91
101	2	13	42	15	48	22	71	24	78
100	6	16	52	18	58	19	61	27	87
95	3	13	42	14	45	19	61	26	84
84	9	10	32	14	45	14	45	22	71
82	7	11	35	12	39	13	42	21	68
Average:		13	42%	18	58%	22	73%	27	88%

Table 5a

Breakdown: Area---Southern Mid-West.

Number of Raters: 12

Evaluation for accuracy.

Corrected Ratings	Sequence Shown.	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
165	12	3	25	9	75	10	83	12	100
152	4	4	33	7	58	7	58	12	100
146	11	10	83	10	83	10	83	11	92
140	8	8	67	9	75	10	83	11	92
130	1	3	25	5	42	9	75	12	100
126	5	6	50	6	50	9	75	11	92
112	10	5	42	9	75	9	75	10	83
105	2	2	17	6	50	9	75	10	83
101	6	5	42	8	67	8	67	10	83
99	3	6	50	7	58	9	75	11	92
87	9	2	17	3	25	6	50	9	75
84	7	6	50	6	50	7	58	8	67
Average:		5	42%	7	59%	9	72%	11	88%

Table 5b

Breakdown: Area---Southern Mid-West.

Number of Raters: 12.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±30%	
		No.	%	No.	%	No.	%	No.	%
159	12	10	83	10	83	11	92	11	92
144	4	6	50	8	67	11	92	11	92
145	11	10	83	10	83	11	92	11	92
141	8	8	67	9	75	10	83	11	92
125	1	6	50	6	50	7	58	11	92
125	5	6	50	6	50	9	75	10	83
117	10	5	42	7	58	8	67	11	92
106	2	2	17	6	50	7	58	10	83
102	6	5	42	8	67	8	67	10	83
106	3	6	50	9	75	9	75	11	92
96	9	5	42	6	50	8	67	9	75
92	7	4	33	5	42	7	58	10	83
Average:		6	51%	8	63%	9	74%	11	88%

Table 6a

Breakdown: Area---Michigan.

Number of Raters: 9

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
165	12	1	11	3	33	4	44	9	100
153	4	1	11	2	22	2	22	8	88
145	11	2	22	4	44	5	55	8	88
140	8	1	11	2	22	3	33	7	77
130	1	1	11	2	22	2	22	5	55
125	5	2	22	4	44	4	44	6	66
111	10	3	33	6	66	6	66	6	66
104	2	1	11	3	33	4	44	7	77
101	6	4	44	4	44	5	55	7	77
98	3	4	44	4	44	4	44	7	77
86	9	2	22	2	22	6	66	7	77
84	7	1	11	3	33	4	44	6	66
Average:		2	21%	3	36%	4	45%	7	77%

Table 6b

Breakdown: Area---Michigan.

Number of Raters: 9.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
158	12	4	44	5	55	6	66	8	88
145	4	2	22	3	33	6	66	7	77
144	11	3	33	4	44	5	55	7	77
134	8	3	33	4	44	4	44	7	77
123	1	2	22	2	22	4	44	6	66
123	5	4	44	4	44	4	44	6	66
116	10	3	33	4	44	5	55	6	66
107	2	1	11	2	22	3	33	7	77
107	6	3	33	3	33	4	44	6	66
111	3	2	22	3	33	3	33	6	66
98	9	3	33	3	33	5	55	6	66
92	7	3	33	3	33	3	33	5	55
Average:		3	31%	3	37%	4	48%	6	71%

Table 7a

Breakdown: Experience---0-6 Months.

Number of Raters: 6

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
152	12	4	67	4	67	4	67	6	100
140	4	3	50	4	67	4	67	6	100
134	11	3	50	4	67	5	83	6	100
129	8	2	33	3	50	5	83	5	83
120	1	4	67	4	67	5	83	6	100
116	5	3	50	4	67	4	67	5	83
103	10	1	17	2	33	3	50	5	83
96	2	3	50	3	50	4	67	5	83
93	6	0	0	1	17	2	33	4	67
91	3	0	0	2	33	3	50	3	50
80	9	1	17	1	17	1	17	3	50
77	7	0	0	2	33	2	33	2	33
Average:		2	33%	3	47%	4	58%	5	78%

Table 7b

Breakdown: Experience---0-6 Months.

Number of Raters: 6.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
145	12	2	33	4	67	6	100	6	100
132	4	2	33	4	67	6	100	6	100
131	11	1	17	4	67	5	83	6	100
129	8	2	33	3	50	5	83	5	83
122	1	3	50	4	67	5	83	6	100
110	5	2	33	2	33	2	33	4	67
108	10	3	50	3	50	3	50	5	83
103	2	4	67	4	67	4	67	5	83
96	6	1	17	2	33	4	67	4	67
95	3	3	50	3	50	3	50	4	67
84	9	0	0	2	33	2	33	4	67
83	7	2	33	2	33	2	33	4	67
Average:		2	35%	3	51%	4	65%	5	82%

Table 8a

Breakdown: Experience---6 Months to 2 Years.

Number of Raters: 16

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
156	12	8	50	9	56	12	75	16	100
144	4	6	37	9	56	11	69	14	88
138	11	5	31	9	56	11	69	14	88
133	8	8	50	10	63	11	69	14	88
123	1	8	50	9	56	10	63	15	94
119	5	8	50	9	56	12	75	15	94
106	10	8	50	10	63	12	75	14	88
99	2	9	56	11	69	13	81	14	88
96	6	6	37	7	44	9	56	12	75
93	3	7	44	9	56	9	56	15	94
83	9	5	31	6	37	6	37	11	69
80	7	2	13	4	25	7	44	11	69
Average:		7	42%	9	53%	10	64%	14	86%

Table 8b

Breakdown: Experience---6 Months to 2 Years.

Number of Raters: 16

Evaluation for consistency.

Average Ratings	Sequence Shown.	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
153	12	6	38	11	69	12	75	15	94
136	4	9	56	11	69	14	88	15	94
136	11	5	31	8	50	12	75	14	88
130	8	6	38	10	63	10	63	14	88
122	1	8	50	9	56	12	75	15	94
116	5	7	44	11	69	12	75	15	94
107	10	8	50	11	69	12	75	14	88
105	2	9	56	10	63	12	75	15	94
105	6	5	31	7	44	8	50	13	81
102	3	8	50	11	69	11	69	15	94
84	9	4	25	6	38	6	38	11	69
83	7	2	13	5	31	6	38	11	69
Average:		6	40%	9	57%	11	66%	14	87%

Table 9a

Breakdown: Experience---2 To 4 Years.

Number of Raters: 19.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
155	12	9	47	14	74	14	74	19	100
143	4	5	26	11	58	16	84	19	100
137	11	10	53	11	58	17	90	19	100
132	8	12	63	15	79	15	79	19	100
122	1	9	47	14	74	16	84	19	100
118	5	9	47	13	69	14	74	19	100
105	10	6	32	8	42	12	63	18	95
98	2	8	42	10	53	12	63	18	95
95	6	6	32	9	47	11	58	16	84
92	3	7	37	8	42	10	53	17	90
81	9	4	21	6	32	8	42	13	69
79	7	3	16	4	21	6	32	15	79
Average:		7	39%	10	54%	13	66%	18	93%

Table 9b

Breakdown: Experience---2 To 4 Years.

Number of Raters: 19.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
147	12	7	37	13	68	16	84	19	100
135	4	10	53	15	79	18	95	19	100
134	11	9	47	12	63	16	84	19	100
131	8	12	63	15	79	15	79	19	100
121	1	9	47	15	79	16	84	19	100
116	5	11	58	13	68	15	79	18	95
111	10	9	47	13	68	15	79	18	95
103	2	3	16	8	42	10	53	18	95
102	6	7	37	9	47	9	47	15	79
98	3	4	21	12	63	13	68	18	95
83	9	5	26	8	42	8	42	13	68
84	7	4	21	6	32	9	47	12	63
Average:		8	39%	12	61%	13	70%	17	91%

Table 10a

Breakdown: Experience---Over 4 Years.

Number of Raters: 29.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
151	12	14	48	18	62	21	73	27	93
140	4	9	31	16	55	19	66	27	93
133	11	20	69	25	86	25	86	27	93
128	8	10	35	15	42	22	76	26	90
119	1	14	48	20	69	25	86	26	90
115	5	13	45	17	59	23	83	27	93
102	10	8	28	12	41	13	45	26	90
96	2	13	45	16	55	19	66	27	93
92	6	11	37	13	45	14	48	27	93
90	3	8	28	12	41	14	48	25	86
79	9	5	17	7	24	8	28	21	73
77	7	9	31	15	52	17	59	23	79
Average:		11	39%	16	53%	18	63%	26	89%

Table 10b

Breakdown: Experience---Over 4 Years.

Number of Raters: 29

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
145	12	13	45	20	69	23	79	27	93
132	4	16	55	22	76	24	83	28	97
133	11	20	69	25	86	25	86	27	93
126	8	13	45	18	62	19	66	26	90
117	1	16	55	22	76	22	76	28	97
113	5	11	38	18	62	21	73	27	93
108	10	9	31	13	45	19	66	25	86
99	2	11	38	13	45	19	66	27	93
97	6	11	38	17	59	19	66	27	93
95	3	10	35	13	45	18	62	26	90
87	9	10	35	11	38	14	48	23	79
82	7	14	48	14	48	14	48	22	76
Average:		13	44%	17	59%	20	67%	26	90%

Table 11a

Breakdown: Education---Initial Time Study Training Received In College.

Number of Raters: 22.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
156	12	13	59	15	68	17	77	19	87
144	4	8	36	13	59	16	73	20	91
138	11	9	41	12	55	15	68	18	82
133	8	9	41	12	55	14	64	17	77
123	1	10	46	15	68	15	68	20	91
119	5	11	50	13	59	14	64	19	87
106	10	9	41	11	50	13	59	18	82
99	2	8	36	11	50	14	64	20	91
96	6	7	32	7	32	11	50	16	73
93	3	6	27	7	32	7	32	18	82
82	9	2	9	5	23	5	23	15	68
80	7	5	23	8	36	9	41	14	64
Average:		8	37%	11	49%	13	58%	18	81%

Table 11b

Breakdown: Education---Initial Time Study Training Received In College.

Number of Raters: 22

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
155	12	11	50	16	73	17	77	19	86
138	4	12	55	15	68	15	68	19	86
138	11	9	41	12	55	15	68	19	86
131	8	5	23	11	50	13	59	17	77
121	1	10	46	15	68	17	77	20	91
112	5	7	32	13	59	13	59	20	91
110	10	12	55	13	59	16	73	18	82
102	2	5	23	12	55	15	68	20	91
101	6	7	32	10	46	12	55	16	73
99	3	10	46	11	50	15	68	17	77
87	9	4	18	6	27	11	50	16	73
82	7	7	32	8	36	11	50	16	73
Average:		8	38%	12	54%	14	64%	18	82%

Table 12a

Breakdown: Education---Initial Time Study Training Received With the Company.

Number of Raters: 45.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
153	12	22	49	30	67	32	71	43	95
141	4	17	38	29	64	31	69	42	93
135	11	25	55	35	78	41	91	42	93
130	8	25	56	32	71	39	87	42	93
121	1	20	44	31	69	37	82	43	95
117	5	18	40	30	67	31	69	42	93
104	10	12	27	20	44	26	58	40	89
97	2	19	42	24	53	31	69	40	89
94	6	14	31	19	42	21	47	36	80
91	3	14	31	22	49	25	55	36	80
80	9	12	27	14	31	19	42	30	67
78	7	7	16	17	38	21	47	34	75
Average:		16	38%	24	56%	28	66%	39	87%

Table 12b

Breakdown: Education---Initial Time Study Training Received With the Company.

Number of Raters: 45

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
147	12	20	44	32	71	34	75	43	95
135	4	21	47	33	73	41	91	43	95
134	11	27	60	34	75	40	89	42	93
131	8	23	51	32	71	35	78	42	93
122	1	20	44	28	62	35	78	43	95
118	5	18	40	30	68	33	73	42	93
110	10	20	44	30	67	35	78	40	89
104	2	14	31	22	49	28	62	40	89
102	6	20	44	25	55	25	55	37	82
99	3	20	44	23	51	29	64	39	87
87	9	17	38	18	40	25	55	33	73
85	7	12	27	17	38	24	53	32	71
Average:		19	43%	27	60%	32	71%	40	88%

Table 13a

Breakdown: Rater Uses His Own Concept of Standard Performance.

Number of Raters: 54

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
153	12	24	44	32	59	35	65	51	94
142	4	24	44	25	46	33	61	50	93
136	11	27	50	36	67	45	83	50	93
130	8	23	43	35	65	43	80	49	91
121	1	24	44	36	67	43	80	49	91
117	5	24	44	37	68	38	70	51	94
104	10	12	22	23	43	30	55	49	91
97	2	20	37	28	52	37	68	48	89
94	6	17	32	21	39	23	43	43	80
92	3	19	35	22	41	28	52	47	87
80	9	13	23	16	30	23	43	38	70
78	7	13	23	20	37	24	44	38	70
Average:		20	37%	28	51%	34	62%	47	87%

Table 13b

Breakdown: Rater Uses His Own Concept of Standard Performance.

Number of Raters: 54

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
147	12	17	32	31	57	39	72	50	93
134	4	24	44	34	63	46	85	52	96
134	11	29	53	39	72	44	81	50	92
128	8	16	30	27	50	43	80	49	91
120	1	27	50	32	59	43	80	49	91
114	5	28	52	35	65	40	74	51	94
108	10	18	33	26	48	36	67	48	69
102	2	20	37	30	56	34	63	48	89
102	6	21	39	30	56	30	56	42	78
98	3	16	30	30	56	37	68	47	87
85	9	14	26	18	33	27	50	42	78
83	7	13	24	14	26	19	35	35	65
Average:		20	38%	29	53%	37	68%	47	87%

Table 14a

Breakdown: Rater Uses Some Film or Other Embodiment of Standard Performance.

Number of Raters: 15.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
155	12	8	53	14	93	15	100	15	100
143	4	4	27	8	53	14	93	15	100
137	11	11	73	11	73	14	93	15	100
131	8	9	60	12	80	12	80	15	100
122	1	8	53	10	67	12	80	15	100
118	5	5	33	11	73	13	87	15	100
104	10	6	40	8	53	11	73	15	100
98	2	10	67	11	73	13	87	15	100
95	6	8	53	9	60	11	73	15	100
92	3	5	33	7	47	8	53	14	93
81	9	2	13	3	20	4	27	13	87
79	7	4	27	6	40	8	53	14	93
Average:		7	44%	9	61%	11	75%	15	98%

Table 14b

Breakdown: Rater Uses Some Film or Other Embodiment of Standard Performance.

Number of Raters: 15

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
150	12	12	80	15	100	15	100	15	100
135	4	12	80	13	87	14	93	15	100
135	11	10	67	11	73	14	93	15	100
129	8	10	67	10	67	11	73	15	100
119	1	9	60	11	73	14	93	15	100
117	5	5	33	10	67	12	80	15	100
111	10	9	60	15	100	15	100	15	100
100	2	7	40	13	87	14	93	15	100
99	6	8	53	9	60	12	80	15	100
99	3	10	67	11	73	13	87	15	100
87	9	4	27	5	33	9	60	13	87
83	7	4	27	7	40	9	60	14	93
Average:		8	56%	11	72%	13	84%	15	98%

Table 15a

Breakdown: Plant employees number less than 101.

Number of raters: 10

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
146	12	3	30	5	50	5	50	9	90
135	4	3	30	4	40	8	80	10	100
129	11	5	50	7	70	7	70	10	100
124	8	5	50	5	50	7	70	10	100
115	1	7	70	7	70	9	90	10	100
111	5	7	70	7	70	7	70	9	90
99	10	2	20	3	30	5	50	9	90
93	2	5	50	7	70	8	80	10	100
89	6	0	0	0	0	1	10	7	70
87	3	2	20	2	20	2	20	9	90
77	9	1	10	1	10	3	30	5	50
74	7	1	10	1	10	1	10	6	60
Average:		3	33%	4	41%	5	53%	9	87%

Table 15b

Breakdown: Plant employees number less than 101.

Number of raters: 10

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
146	12	3	30	5	50	5	50	9	90
127	4	6	60	9	90	9	90	10	100
130	11	5	50	7	70	7	70	10	100
126	8	5	50	5	50	7	70	10	100
117	1	4	40	8	80	8	80	10	100
106	5	5	50	6	60	8	80	8	80
103	10	3	30	6	60	6	60	9	90
98	2	5	50	7	70	7	70	10	100
91	6	0	0	0	0	3	30	7	70
91	3	2	20	4	40	5	50	9	90
78	9	1	10	3	30	3	30	5	50
77	7	1	10	3	30	4	40	6	60
Average:		3	33%	5	53%	6	60%	9	86%

Table 16a

Breakdown: Plant employees number 101-1000.

Number of raters: 37.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
153	12	20	54	24	65	26	70	34	92
141	4	15	41	23	62	25	68	33	84
135	11	20	54	27	73	30	81	33	84
130	8	15	41	22	60	29	78	32	87
120	1	20	54	25	68	31	84	33	84
116	5	19	51	25	68	28	76	35	95
103	10	6	16	13	35	15	41	34	92
97	2	15	41	20	54	28	76	34	92
93	6	15	41	16	43	19	51	32	87
91	3	15	41	20	54	23	62	30	81
80	9	10	27	11	30	16	43	28	76
78	7	8	22	17	46	20	54	29	78
Average:		15	40%	20	55%	24	65%	32	87%

Table 16b

Breakdown: Plant employees number 101-1000.

Number of raters: 37.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
144	12	15	41	20	54	29	78	34	92
134	4	19	51	24	65	31	84	35	95
133	11	24	65	28	76	31	84	33	89
138	8	11	30	19	51	29	78	32	87
119	1	21	57	28	76	31	84	33	89
117	5	16	43	25	68	27	73	35	95
109	10	14	38	21	57	26	70	32	87
100	2	16	43	21	57	27	73	34	92
101	6	14	38	19	51	23	62	31	84
96	3	16	43	18	49	23	62	31	84
85	9	9	24	11	30	19	51	28	76
82	7	16	43	17	46	18	49	26	70
Average:		16	43%	21	57%	26	71%	32	86%

Table 17a

Breakdown: Plant employees number greater than 1000.

Number of raters: 21

Evaluation for accuracy.

Corrected Ratings:	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
156	12	12	57	14	67	16	76	21	100
144	4	7	33	12	57	16	76	21	100
138	11	9	43	12	57	17	81	20	96
133	8	12	57	15	72	16	76	21	100
123	1	10	48	13	62	14	67	21	100
119	5	12	57	13	62	14	67	21	100
106	10	11	54	15	72	16	76	19	91
99	2	9	43	10	48	14	67	18	86
96	6	10	48	12	57	12	57	16	76
93	3	6	29	8	38	9	43	19	91
82	9	4	19	7	33	7	33	14	67
79	7	1	5	5	24	7	33	16	76
Average:		9	41%	11	54%	13	63%	19	90%

Table 17b

Breakdown: Plant employees number greater than 1000.

Number of raters: 21

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
149	12	13	62	14	67	20	96	21	100
136	4	14	67	17	81	20	96	21	100
135	11	10	48	13	62	20	96	21	100
130	8	11	53	15	72	16	76	21	100
133	1	10	48	13	62	14	67	21	100
117	5	9	43	12	57	14	67	20	96
108	10	10	48	15	72	17	81	19	91
106	2	6	29	11	53	14	67	19	91
104	6	7	33	12	57	13	62	18	86
101	3	12	57	13	62	17	81	20	96
88	9	7	33	11	53	12	57	18	86
85	7	6	29	9	43	11	53	16	76
Average:		10	46%	13	62%	16	75%	20	94%

Table 18a

Breakdown: Size of town less than 5000.

Number of raters: 17

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
150	12	14	83	15	88	15	88	17	100
139	4	8	47	13	77	14	83	17	100
133	11	12	71	14	83	16	94	17	100
128	8	4	24	8	47	13	75	16	94
119	1	13	77	15	88	15	88	17	100
114	5	10	59	13	75	15	88	16	94
102	10	3	18	5	29	5	29	16	94
95	2	8	47	10	59	15	88	17	100
93	6	6	35	6	35	6	35	16	94
90	3	6	35	12	71	13	75	16	94
79	9	4	24	6	35	6	35	12	71
77	7	7	41	10	59	11	65	14	83
Average:		8	47%	11	62%	12	71%	16	94%

Table 18b

Breakdown: Size of town less than 5000.

Number of raters: 17.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
146	12	11	65	15	88	15	88	17	100
134	4	9	53	12	71	13	77	17	100
134	11	12	71	14	83	15	88	17	100
128	8	4	24	8	47	13	77	16	94
119	1	13	77	15	88	15	88	17	100
112	5	7	41	11	65	14	83	16	94
109	10	7	41	11	65	14	83	16	94
98	2	11	65	12	71	14	83	17	100
93	6	6	35	6	35	8	47	16	94
90	3	6	35	12	71	13	77	16	94
83	9	6	35	9	53	10	59	13	77
77	7	7	41	10	59	11	65	14	83
Average:		8	49%	11	66%	14	81%	16	94%

Table 19a

Breakdown: Size of town 5000 - 10,000.

Number of raters: 7.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown.	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
161	12	2	29	2	29	2	39	6	86
149	4	0	0	1	14	2	29	6	86
143	11	3	43	3	43	4	57	6	86
137	8	1	14	4	57	6	86	6	86
127	1	2	29	3	43	4	57	7	100
133	5	4	57	5	71	5	71	6	86
109	10	2	29	4	57	5	71	6	86
102	2	2	29	3	43	4	57	6	86
99	6	2	29	2	29	5	71	6	86
96	3	1	14	1	14	3	43	6	86
84	9	1	14	2	29	3	43	4	57
82	7	3	43	3	43	3	43	5	71
Average:		2	37%	3	39%	4	55%	6	83%

Table 19b

Breakdown: Size of town 5,000 - 10,000.

Number of raters: 7.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
153	12	1	14	3	43	4	57	6	86
138	4	2	29	4	57	6	86	6	86
140	11	3	43	4	57	4	57	6	86
137	8	1	14	4	57	6	86	6	86
124	1	3	43	4	57	5	71	7	100
123	5	4	57	5	71	5	71	6	86
117	10	3	43	3	43	3	43	6	86
106	2	3	43	3	43	4	57	6	86
104	6	3	43	4	57	4	57	6	86
110	3	5	71	5	71	5	71	6	86
89	9	2	29	2	29	3	43	4	57
86	7	2	29	3	43	3	43	5	71
Average:		3	38%	4	52%	4	62%	6	83%

Table 20a

Breakdown: Size of town 10,000 - 25,000.

Number of raters: 19

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
153	12	8	42	11	58	12	63	19	100
142	4	7	37	9	47	12	63	19	100
136	11	9	47	12	63	16	84	19	100
130	8	8	42	11	58	16	84	19	100
121	1	8	42	15	79	18	95	19	100
117	5	8	42	10	53	14	74	19	100
104	10	5	26	8	42	12	63	17	90
97	2	6	32	8	42	9	47	19	100
94	6	7	37	8	42	8	42	16	84
92	3	1	5	2	11	5	26	16	84
80	9	3	16	3	16	6	32	12	63
78	7	1	5	5	26	7	37	15	79
Average:		6	31%	9	45%	11	59%	17	92%

Table 20b

Breakdown: Size of town 10,000 - 25,000

Number of raters: 19

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
146	12	2	11	12	63	13	69	19	100
132	4	10	53	17	90	18	95	19	100
133	11	10	53	16	84	18	95	19	100
126	8	6	32	10	53	15	79	19	100
122	1	9	47	14	74	18	95	19	100
115	5	8	42	10	53	16	84	19	100
105	10	7	37	8	42	12	63	18	95
104	2	5	26	10	53	13	69	19	100
103	6	6	32	12	63	14	74	16	84
98	3	4	21	12	63	13	69	17	90
85	9	4	21	4	21	8	42	15	79
85	7	7	37	10	53	11	58	14	74
Average:		7	34%	11	59%	14	74%	18	94%

Table 21a

Breakdown: Size of town 25,000 - 50,000.

Number of Raters: 10.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown.	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
153	13	4	40	7	70	7	70	10	100
141	4	6	60	7	70	8	80	9	90
135	11	5	50	6	60	9	90	9	90
130	8	3	30	7	70	8	80	9	90
121	1	4	40	5	50	6	60	10	100
117	5	2	20	4	40	4	40	10	100
104	10	4	40	5	50	7	70	9	90
97	2	4	40	6	60	8	80	8	80
94	6	3	30	6	60	6	60	6	60
93	3	6	60	7	70	8	80	9	90
80	9	4	40	5	50	6	60	7	70
78	7	2	20	3	30	4	40	7	70
Average:		4	39%	6	57%	7	68%	9	86%

Table 21b

Breakdown: Size of town 25,000 - 50,000.

Number of raters: 10.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
147	12	4	40	5	50	6	60	10	100
133	4	6	60	8	80	9	90	10	100
134	11	5	50	6	60	9	90	9	90
126	8	1	10	4	40	7	70	9	90
120	1	4	40	5	50	7	70	10	100
117	5	2	20	4	40	4	40	10	100
106	10	3	30	7	70	8	80	9	90
102	2	4	40	6	60	6	60	8	80
106	6	0	0	2	20	5	50	8	80
87	3	4	40	6	60	8	80	10	100
85	9	3	30	4	40	6	60	8	80
81	7	4	40	4	40	4	40	7	70
Average:		3	33%	5	51%	7	66%	9	90%

Table 23a

Breakdown: Size of town 50,000 - 100,000.

Number of raters: 7.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
159	12	5	71	5	71	7	100	7	100
147	4	3	43	3	43	4	57	7	100
141	11	3	43	7	100	7	100	7	100
136	8	4	57	5	71	7	100	7	100
126	1	3	43	4	57	4	57	6	85
121	5	4	57	4	57	6	85	7	100
108	10	3	43	3	43	4	57	6	85
101	2	1	14	3	43	6	85	6	85
98	6	0	0	4	57	5	71	7	100
95	3	2	28	2	28	3	43	7	100
83	9	0	0	1	14	3	43	6	85
81	7	1	14	1	14	1	14	5	71
Average:		2	35%	4	50%	5	68%	7	93%

Table 22b

Breakdown: Size of town 50,000 - 100,000

Number of raters: 7.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
154	12	5	71	7	100	7	100	7	100
137	4	3	43	5	71	7	100	7	100
139	11	3	43	6	85	7	100	7	100
133	8	5	71	6	85	6	85	7	100
118	1	3	43	5	71	5	71	5	71
121	5	4	57	4	57	6	85	7	100
117	10	3	43	5	71	5	71	7	100
101	2	1	14	3	43	6	85	6	85
103	6	3	43	4	57	4	57	7	100
101	3	2	28	4	57	6	85	7	100
96	9	3	43	5	71	6	85	6	85
93	7	4	57	4	57	4	57	7	100
Average:		3	46%	5	69%	6	82%	7	95%

Table 23a

Breakdown: Size of town over 100,000.

Number of raters: 11.

Evaluation for accuracy.

Corrected Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
154	12	2	18	4	36	5	46	7	64
142	4	3	27	3	27	4	36	8	73
136	11	2	18	4	36	6	55	8	73
131	8	5	46	5	46	5	46	7	64
121	1	2	18	4	36	7	64	8	73
117	5	2	18	4	36	5	46	9	82
104	10	3	27	6	55	6	55	9	82
97	2	8	73	8	73	8	73	8	73
94	6	5	46	6	55	6	55	9	82
92	3	4	36	5	46	5	46	8	73
80	9	2	18	2	18	4	36	9	82
78	7	2	18	4	36	5	46	8	73
Average:		3	30%	5	42%	6	50%	8	74%

Table 23b

Breakdown: Size of town over 100,000.

Number of raters: 11.

Evaluation for consistency.

Average Ratings	Sequence Shown	±5%		±7½%		±10%		±20%	
		No.	%	No.	%	No.	%	No.	%
149	12	4	36	5	46	5	46	7	64
138	4	3	27	4	36	5	46	8	73
131	11	4	36	6	55	6	55	8	73
128	8	5	46	5	46	6	55	7	64
120	1	3	27	5	46	7	64	8	73
107	5	4	36	5	46	8	73	9	82
109	10	4	36	5	46	5	46	8	73
103	2	5	46	5	46	6	55	8	73
100	6	5	46	6	55	6	55	8	73
101	3	4	36	4	36	6	55	7	64
87	9	2	18	2	18	4	36	7	64
83	7	2	18	2	18	2	18	6	55
Average:		4	34%	5	41%	6	50%	8	69%

Table 24

Results of Analysis-of-Variance Tests

Breakdown	F_{c05}	F_{c10}	F_{05}	Significant
Area	3.21	6.64	2.95	Yes
Experience	1.11	1.67	2.88	No
Education	6.48	7.11	243-F_{c05} 4.84F_{c10}	At 10%
Concept of "standard performance"	3.05	8.64	4.84	At 10%
No. of employees	1.03	3.30	3.44	No
Size of city	2.03	2.60	2.38	Barely at 10%

F_{c05} and F_{c10} indicate computed F's at the ±5% and ±10% levels of accuracy.

F_{05} is tabulated values of F at the 5% level of significance.

Fig. 1

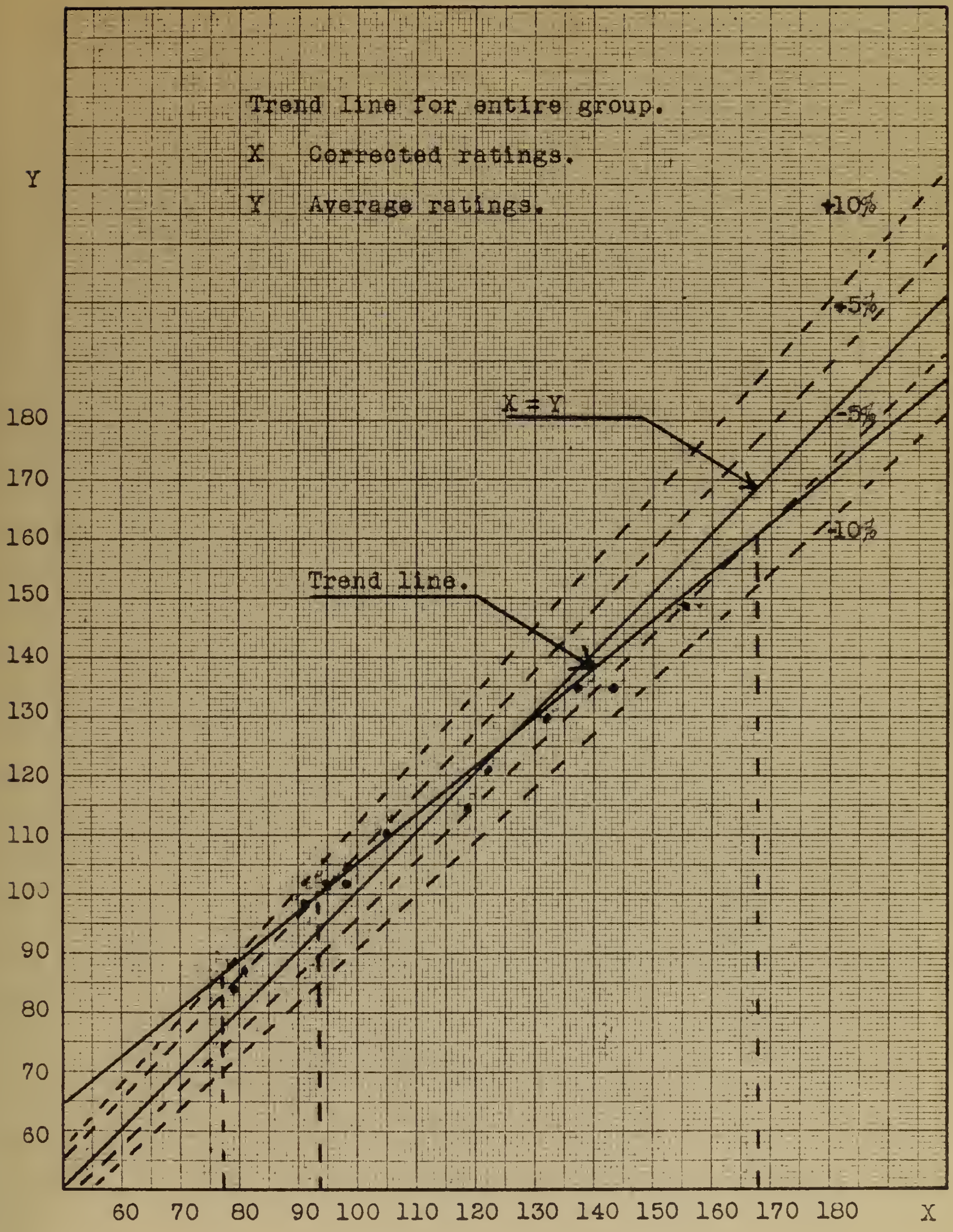

Trend line for entire group.
X Corrected ratings.
Y Average ratings.
+10%
+5%
X = Y
-5%
-10%
Trend line.
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 2

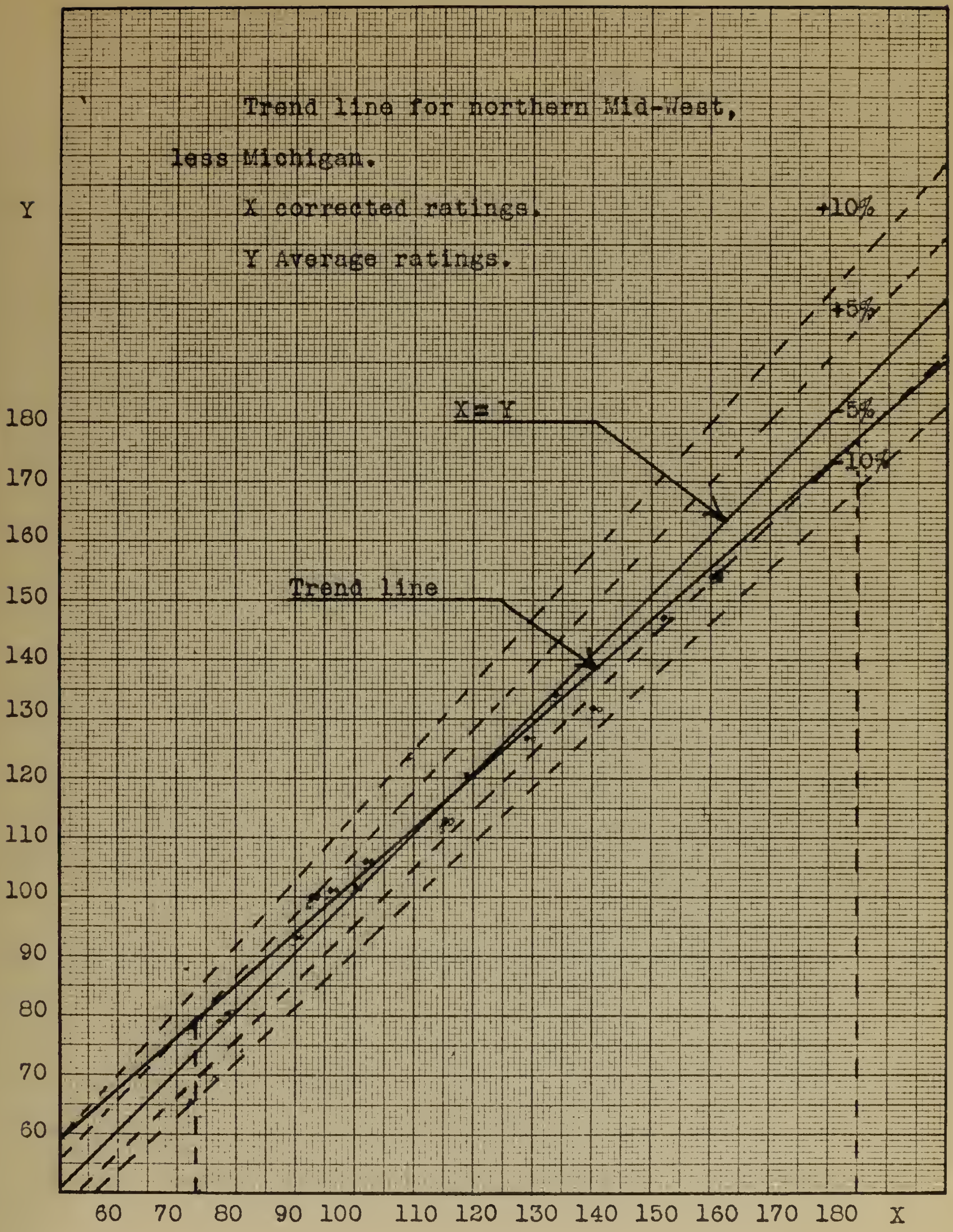

Trend line for northern Mid-West,
less Michigan.
X corrected ratings.
Y Average ratings.
Y
X
+10%
+5%
-5%
-10%
X = Y
Trend line
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180

Fig. 3

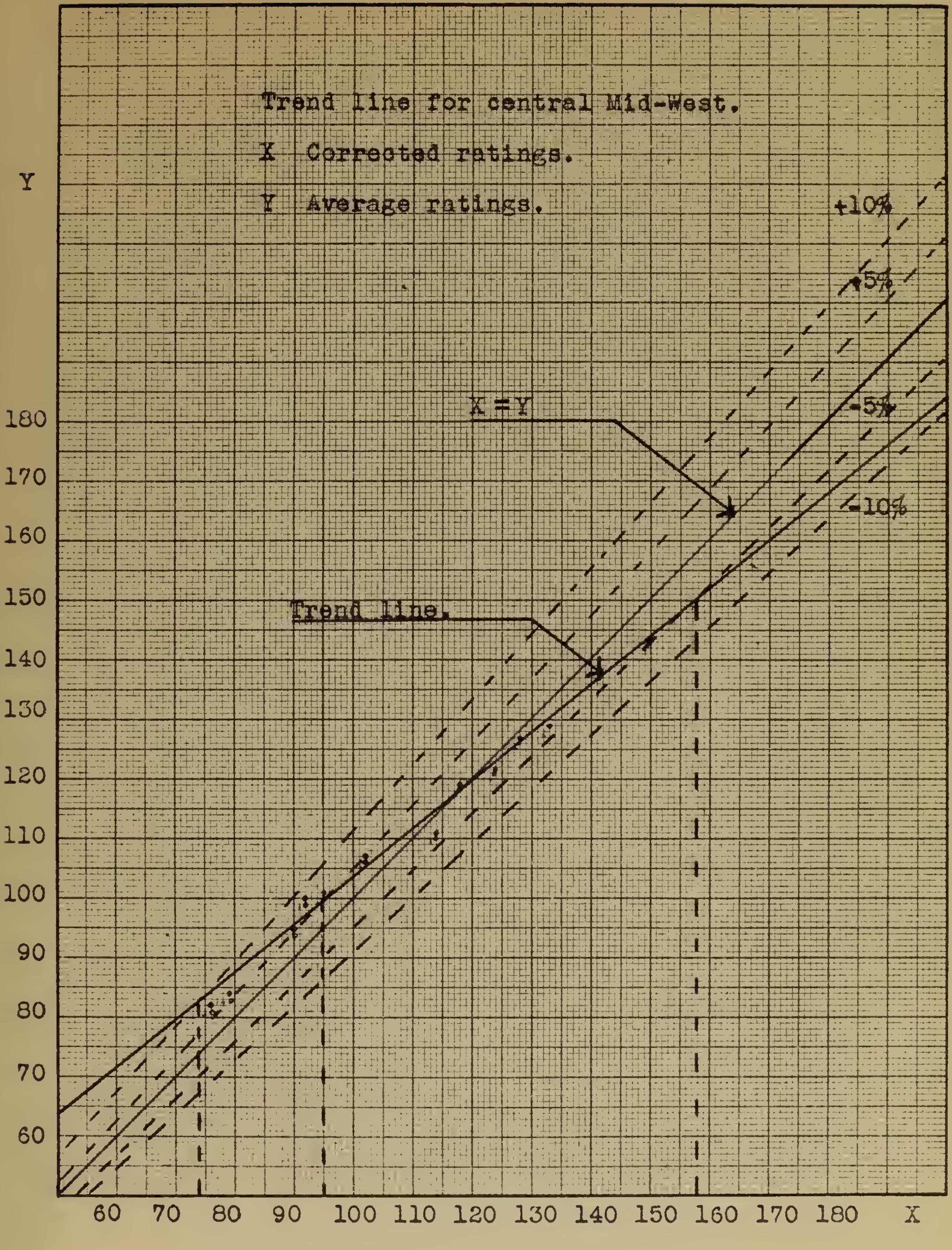

Trend line for central Mid-West.
X Corrected ratings.
Y Average ratings.
Y
+10%
+5%
X = Y
-5%
-10%
Trend line.
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 4

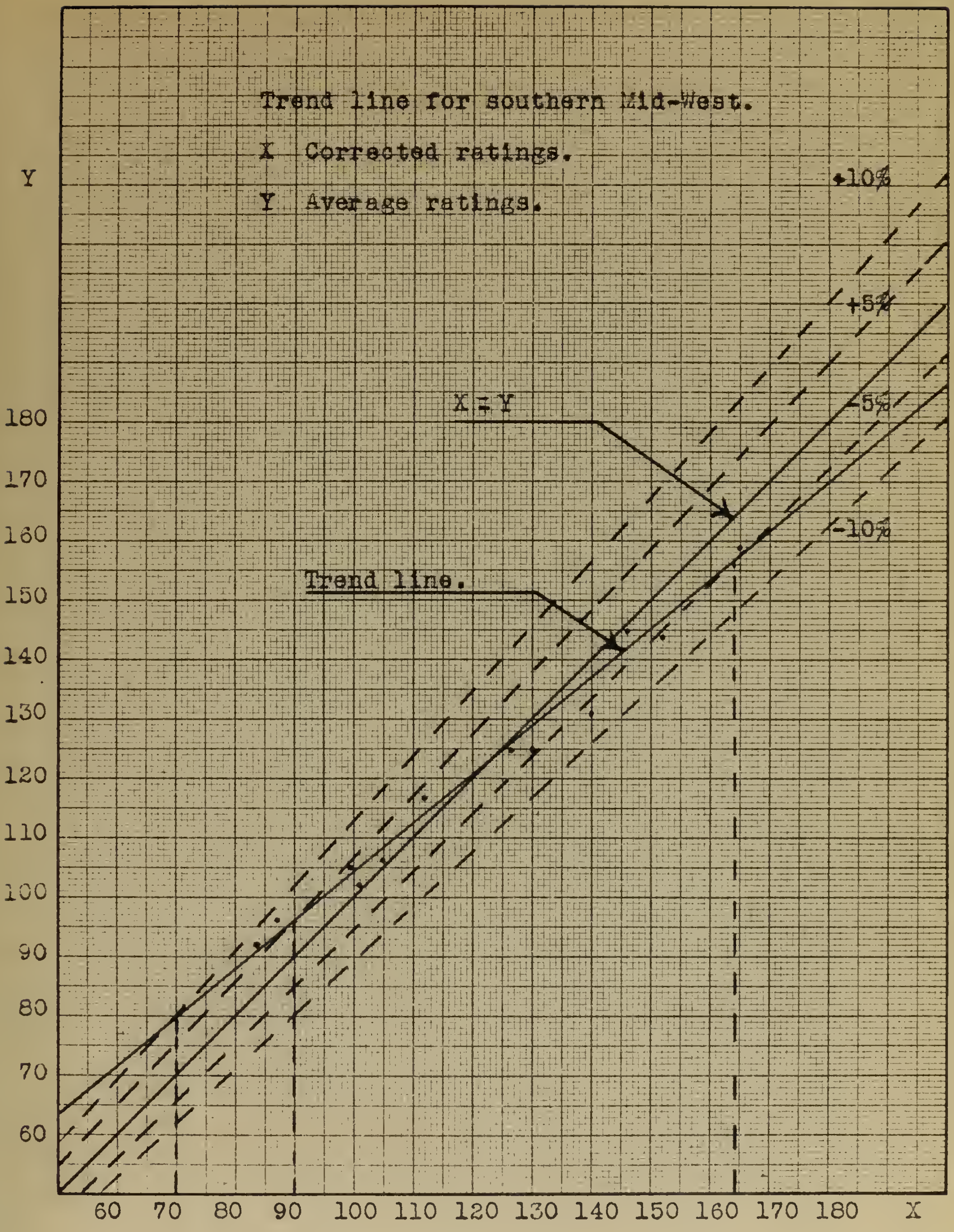

Trend line for southern Mid-West.
X Corrected ratings.
Y Average ratings.
Y
X
+10%
+5%
-5%
-10%
X = Y
Trend line.
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180

Fig. 5

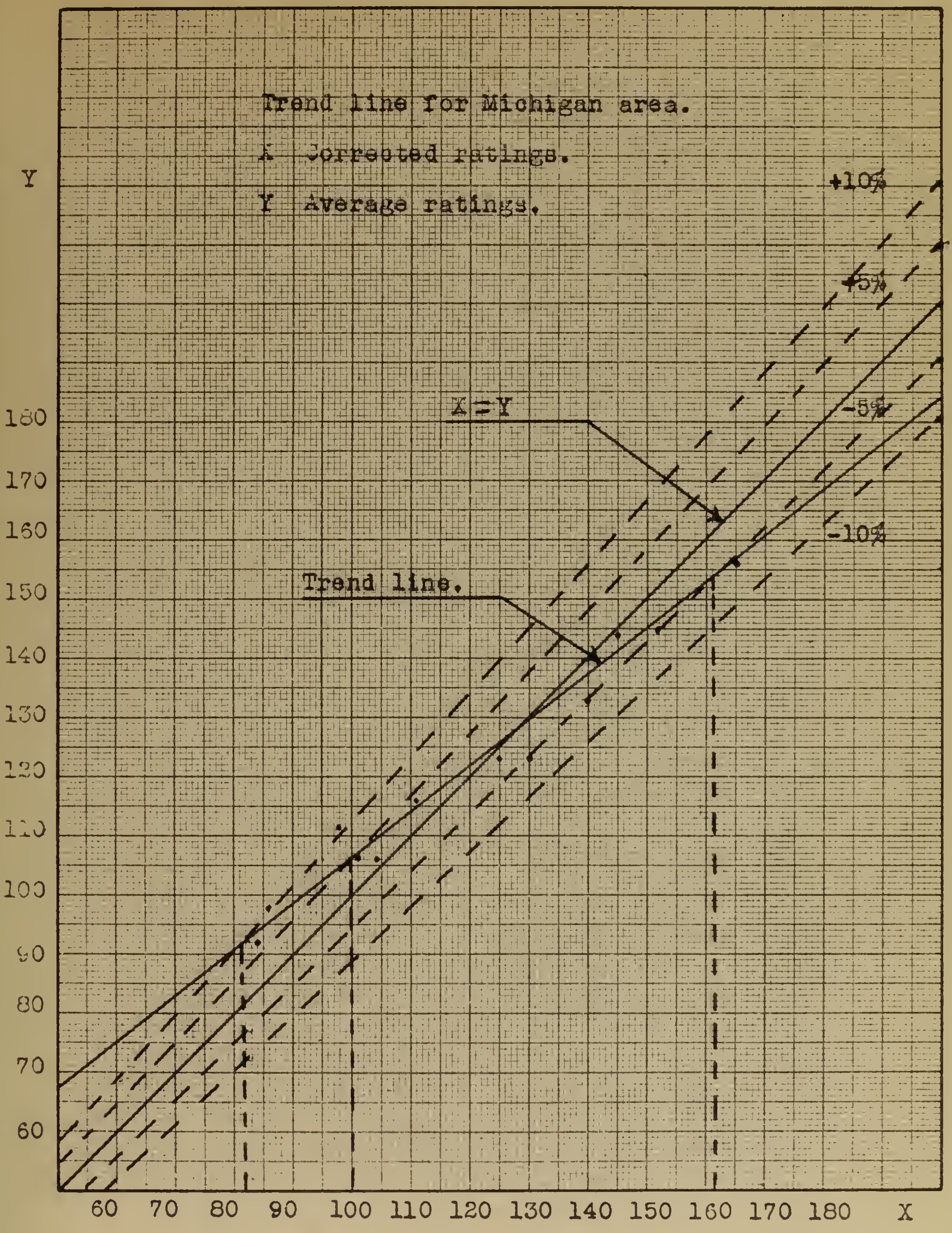

Trend line for Michigan area.
X Corrected ratings.
Y Average ratings.
Y
X
+10%
+5%
-5%
-10%
X = Y
Trend line.
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180

Fig. 6

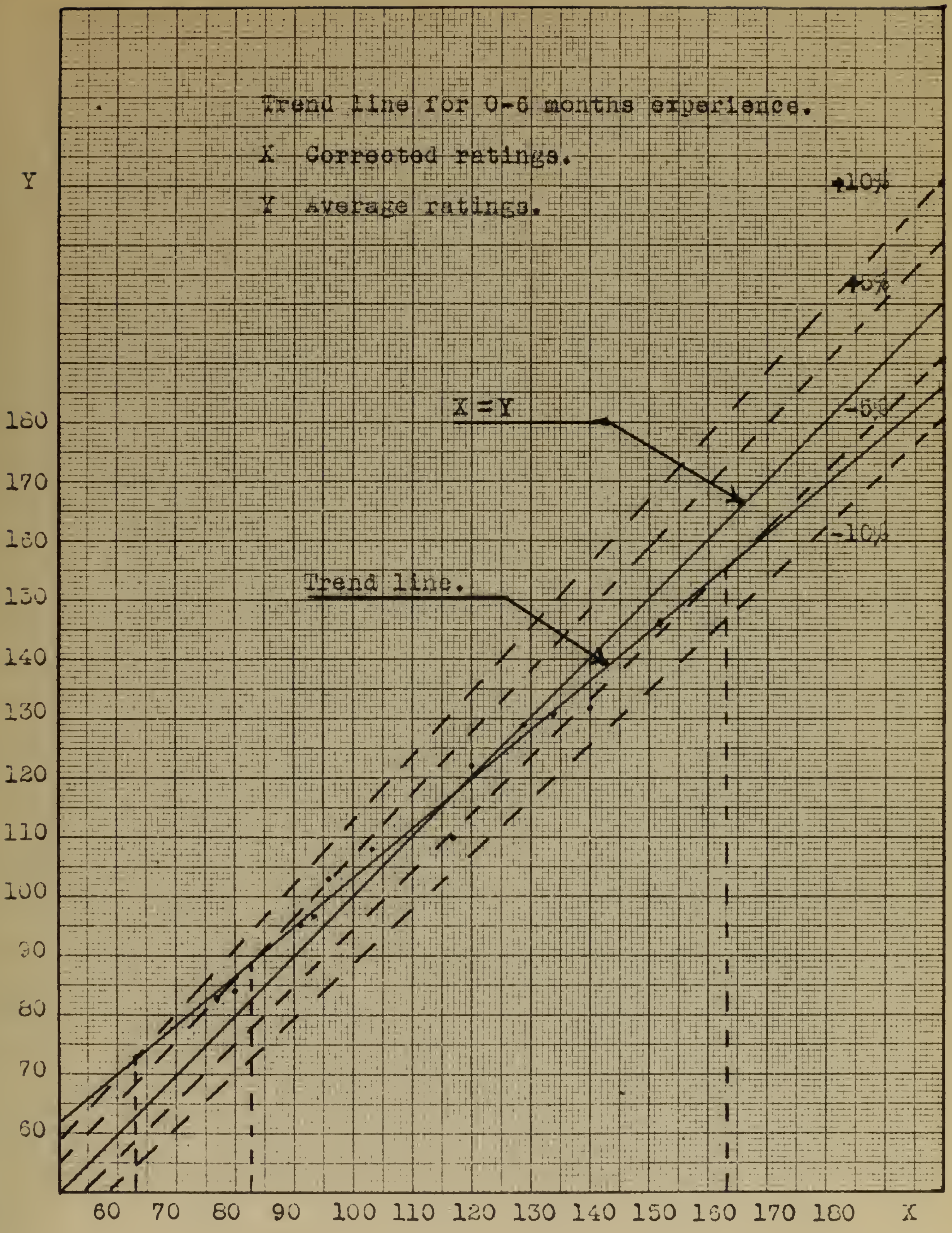

Trend line for 0-6 months experience.
X Corrected ratings.
Y Average ratings.
Y
+10%
+5%
-5%
-10%
X = Y
Trend line.
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 7

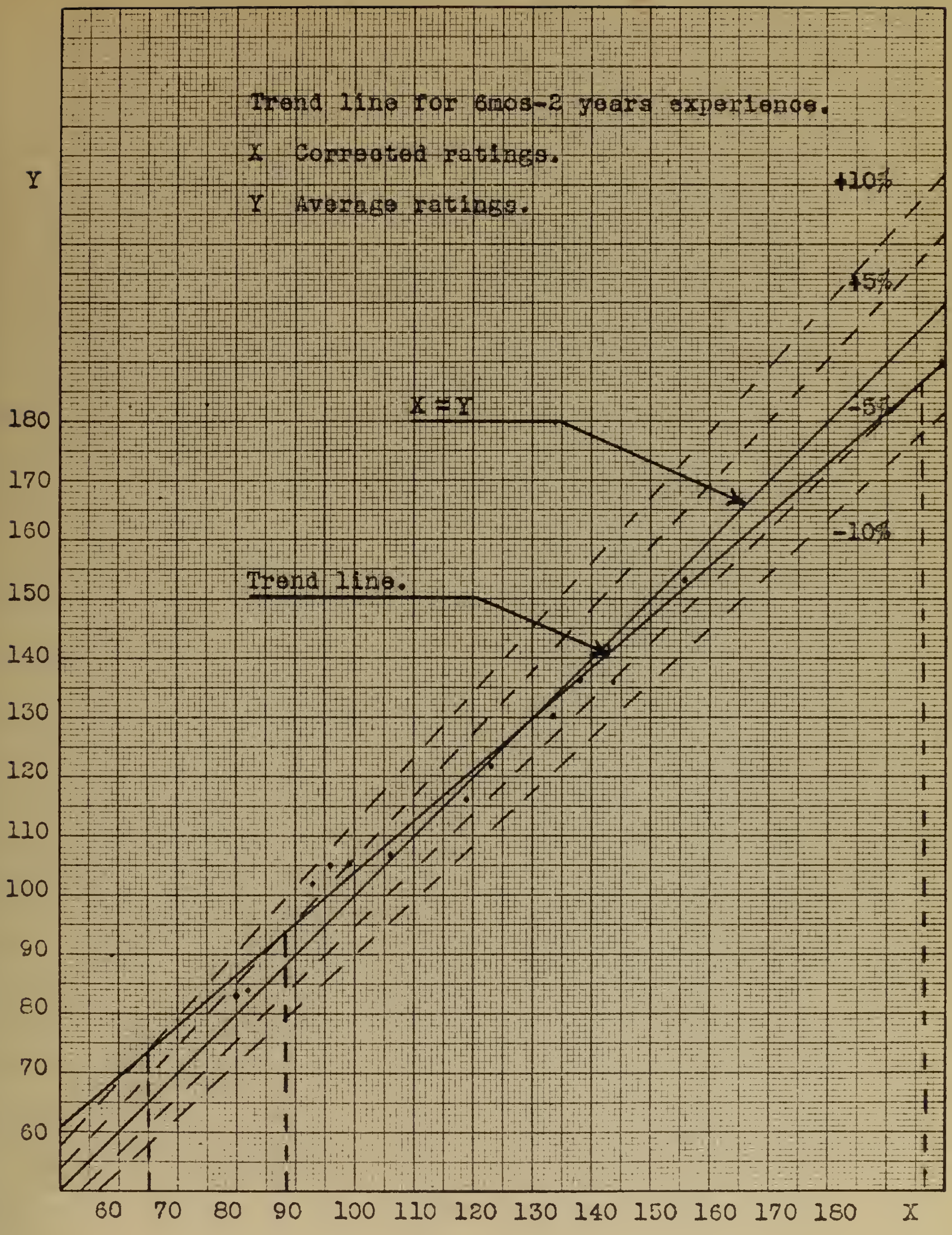

Trend line for 6mos-2 years experience.
X Corrected ratings.
Y Average ratings.
+10%
+5%
-5%
-10%
X = Y
Trend line.
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 8

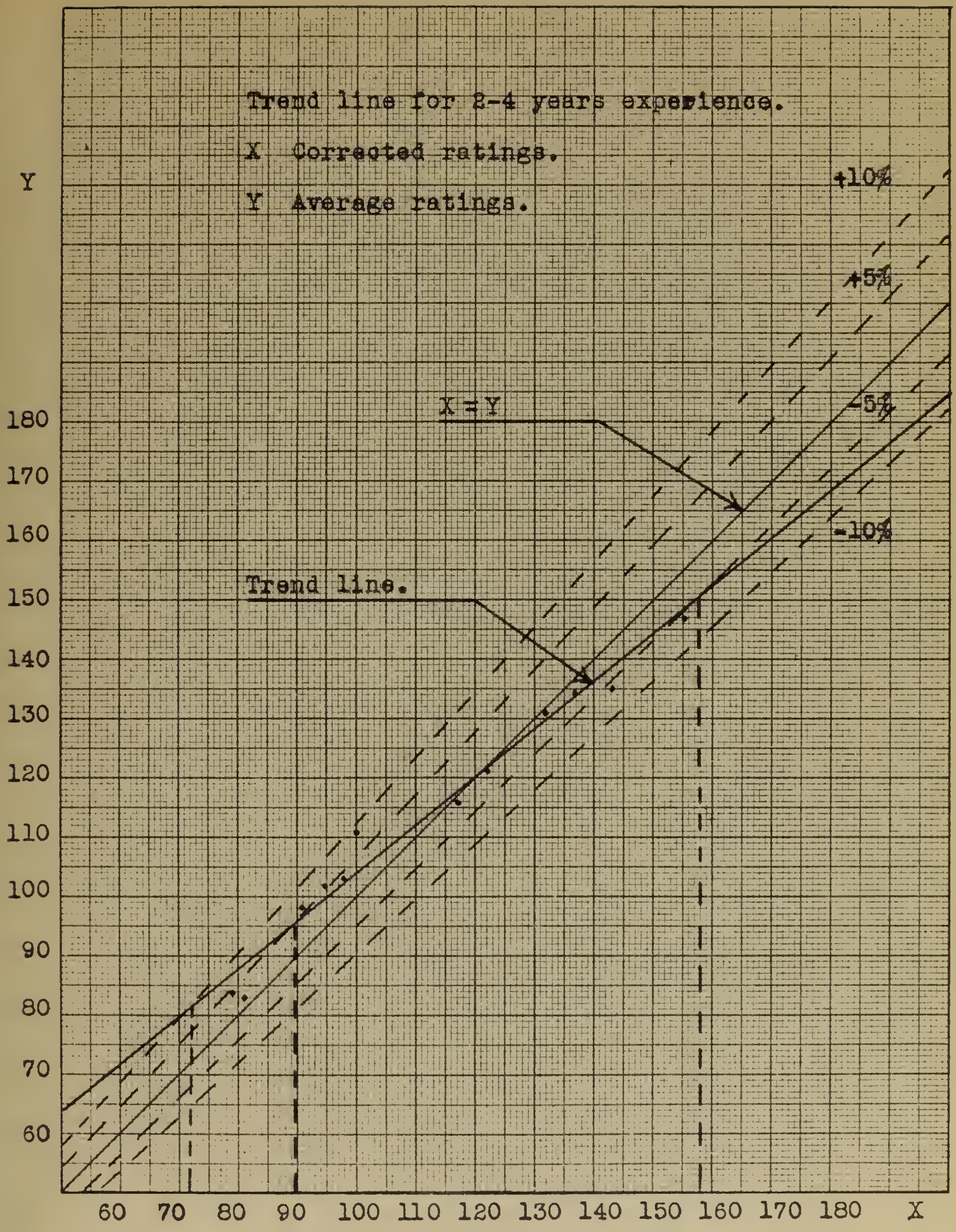

Trend line for 2-4 years experience.
X Corrected ratings.
Y Average ratings.
X = Y
Trend line.
+10%
+5%
-5%
-10%
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 9

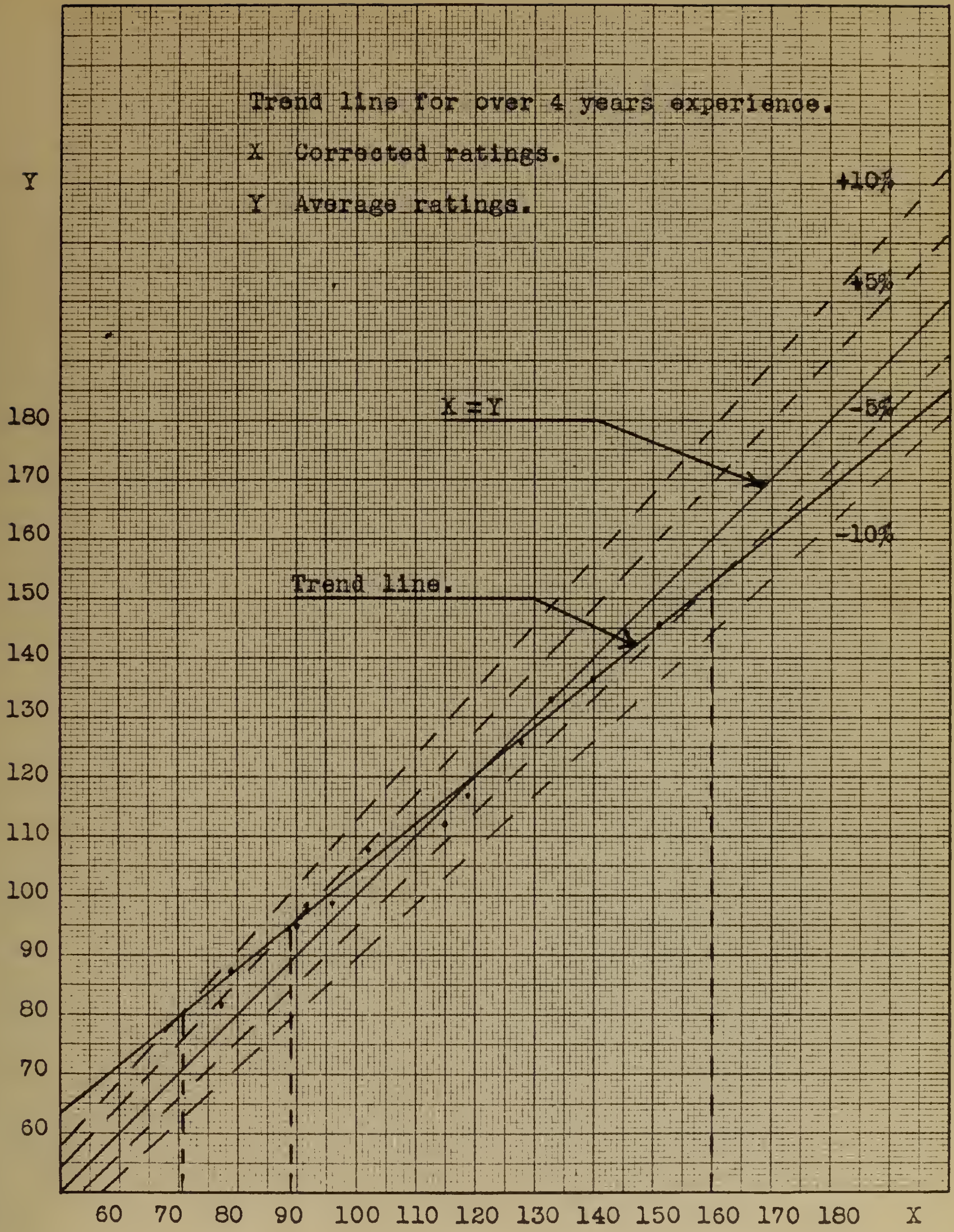

Trend line for over 4 years experience.
X Corrected ratings.
Y Average ratings.
+10%
+5%
-5%
-10%
X = Y
Trend line.
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 10

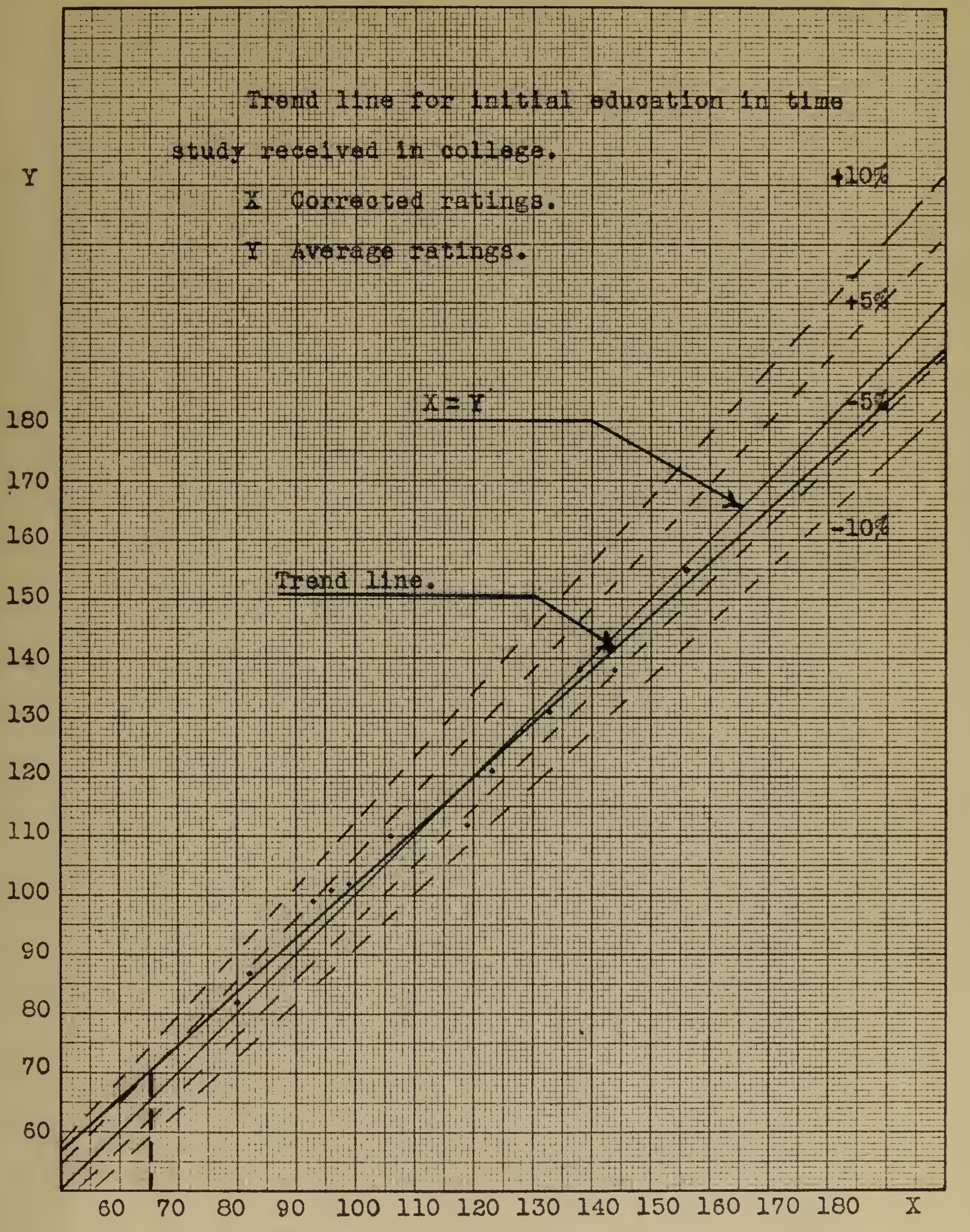

Trend line for initial education in time study received in college.
X Corrected ratings.
Y Average ratings.
X = Y
Trend line.
+10%
+5%
-5%
-10%
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 11

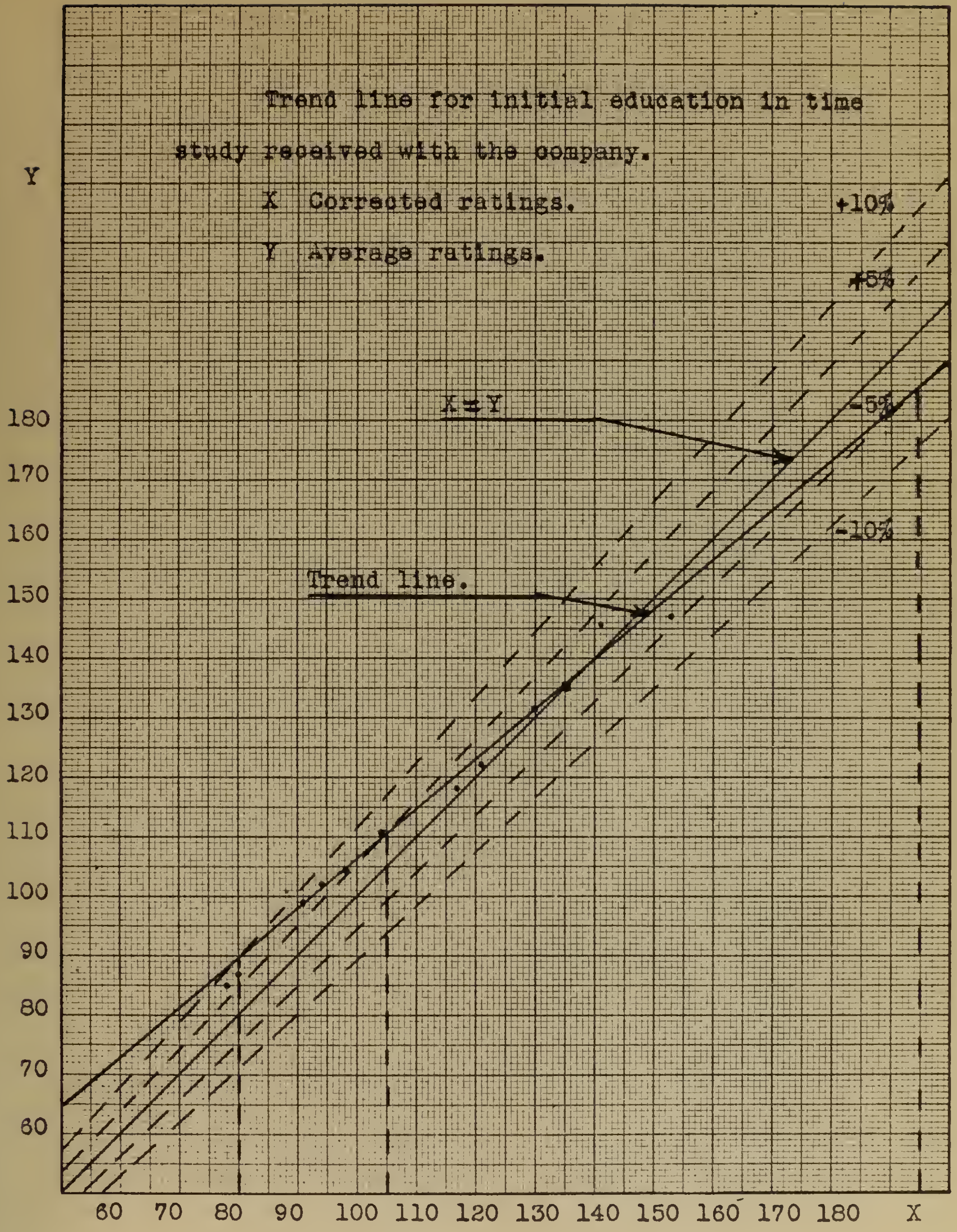

Trend line for initial education in time
study received with the company.
X Corrected ratings.
Y Average ratings.
+10%
+5%
-5%
-10%
X = Y
Trend line.
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 12

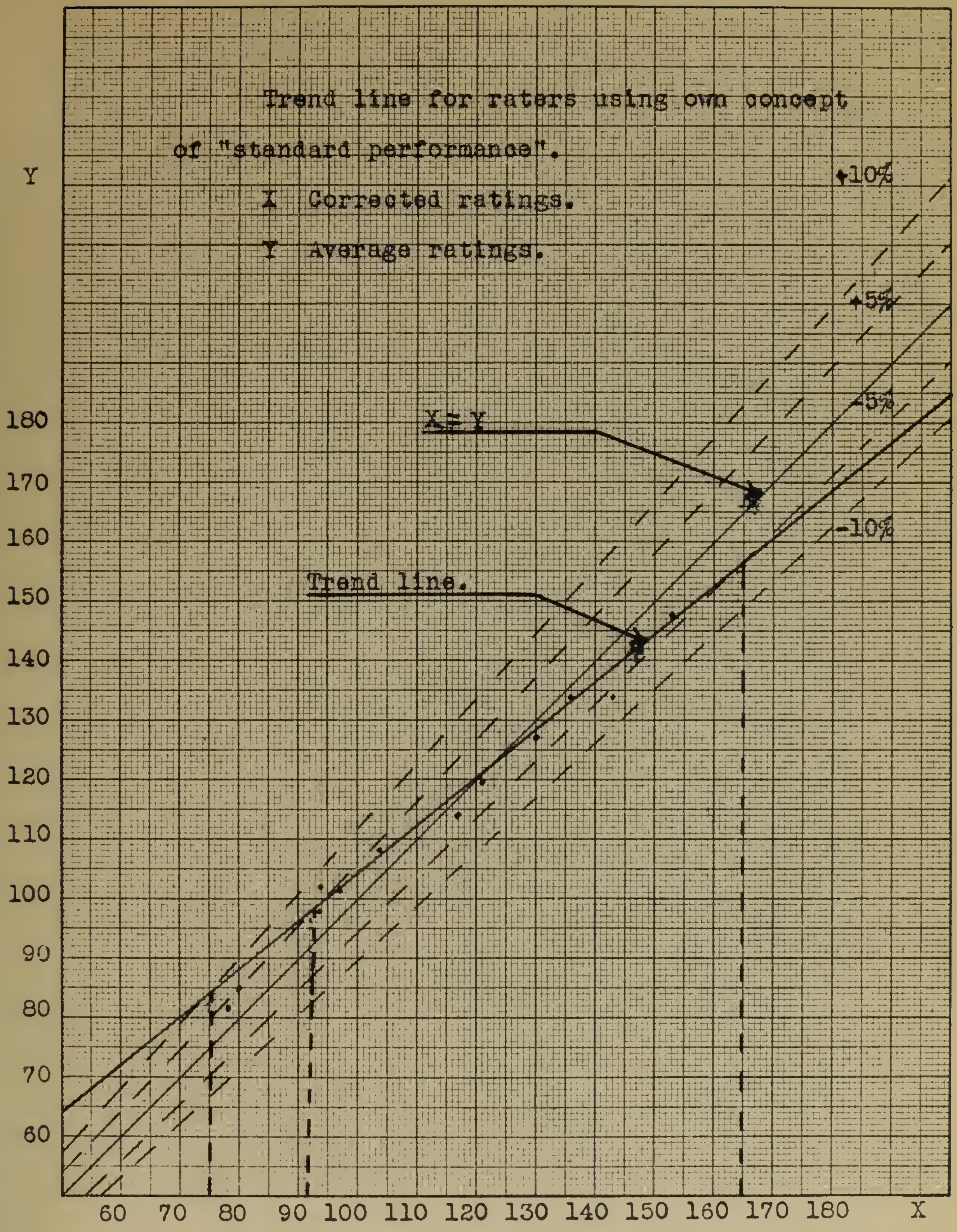
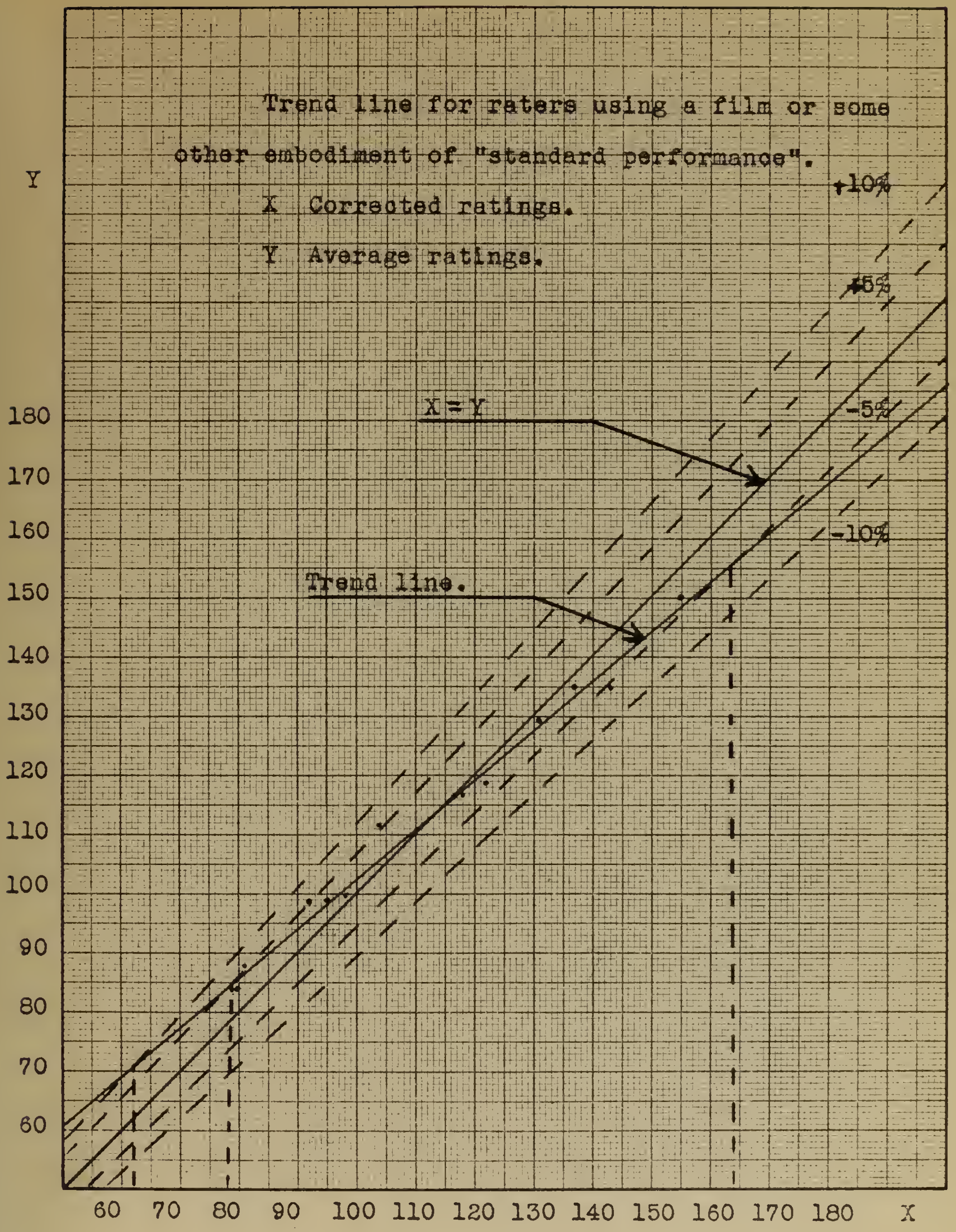

Trend line for raters using own concept
of "standard performance".
X Corrected ratings.
Y Average ratings.
X=Y
Trend line.
+10%
+5%
-5%
-10%
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 13



Trend line for raters using a film or some other embodiment of "standard performance".

X Corrected ratings.

Y Average ratings.

Fig. 14

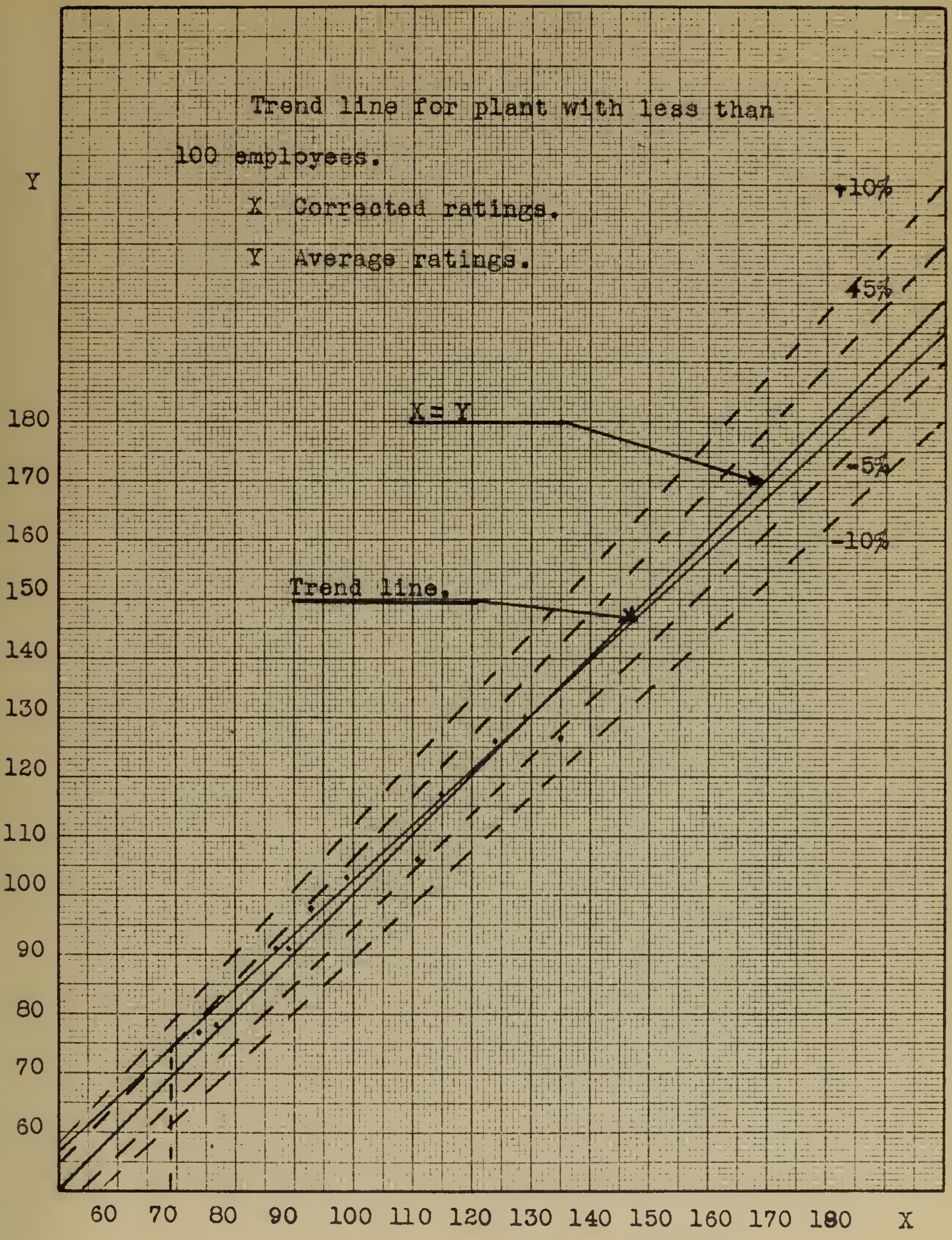

Trend line for plant with less than
100 employees.
X Corrected ratings.
Y Average ratings.
Y
X = Y
Trend line.
+10%
+5%
-5%
-10%
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 15

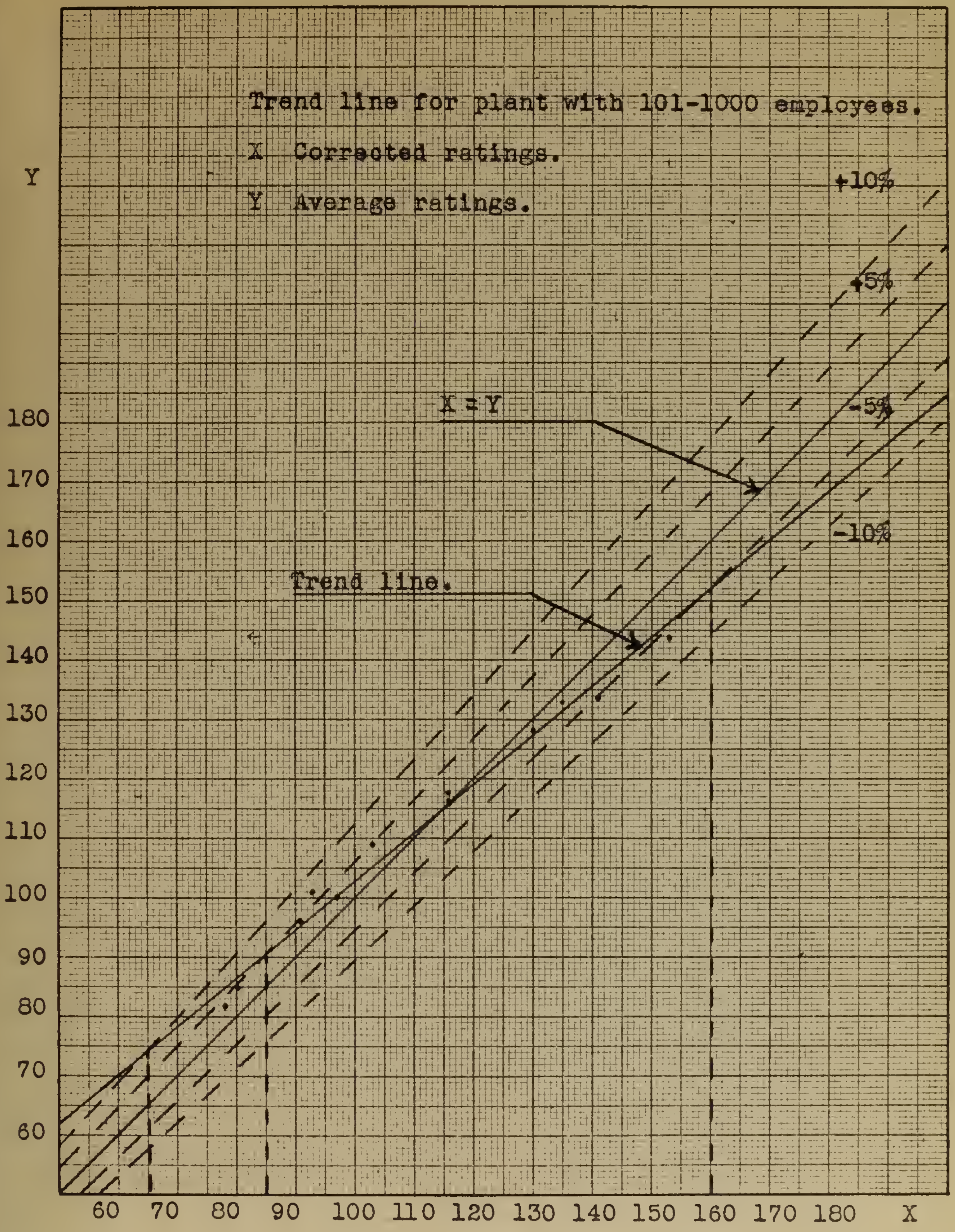

Trend line for plant with 101-1000 employees.
X Corrected ratings.
Y Average ratings.
Y
+10%
+5%
X = Y
-5%
-10%
Trend line.
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 16

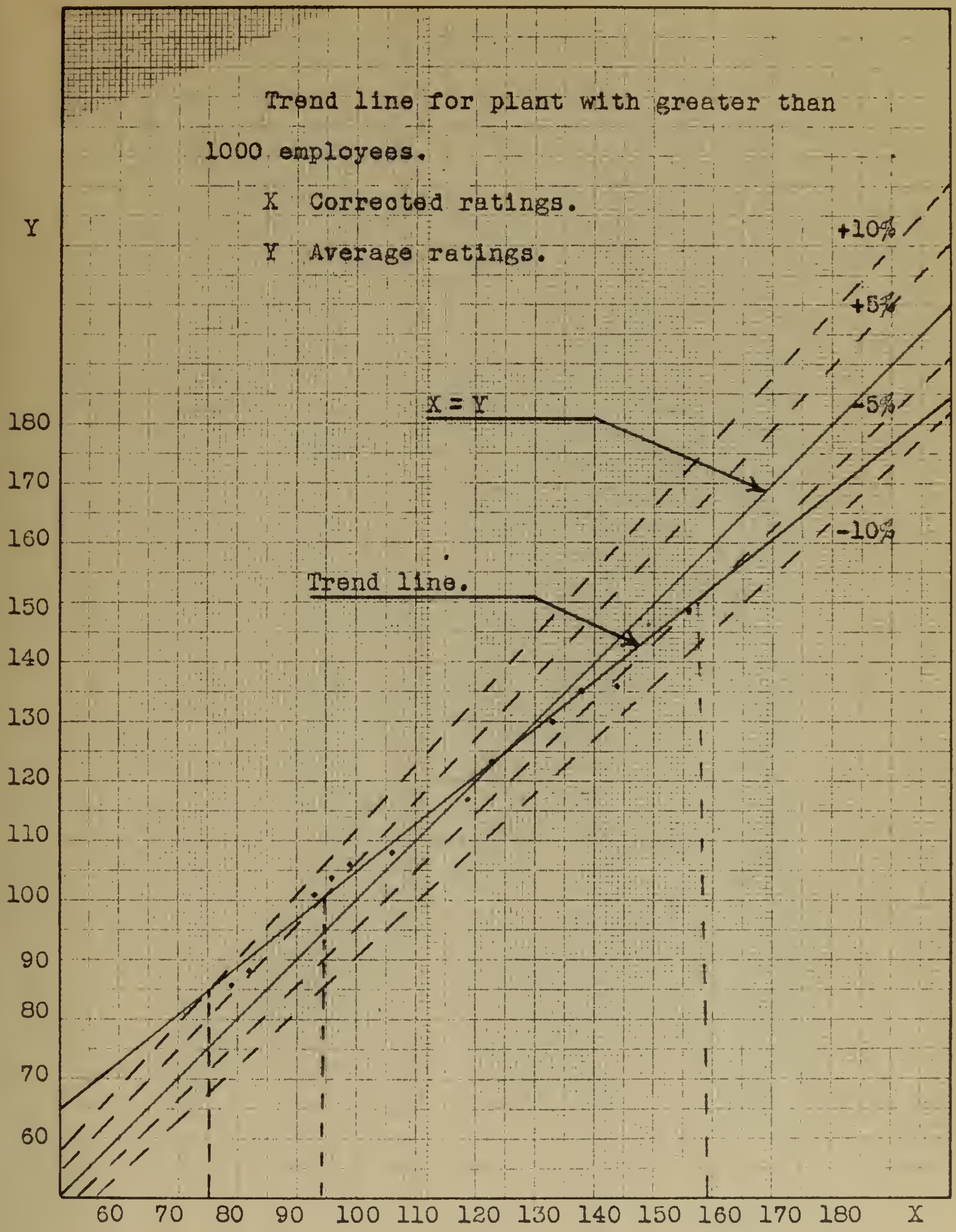

Trend line for plant with greater than 1000 employees.
X Corrected ratings.
Y Average ratings.
+10%
+5%
X = Y
-5%
-10%
Trend line.
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 17

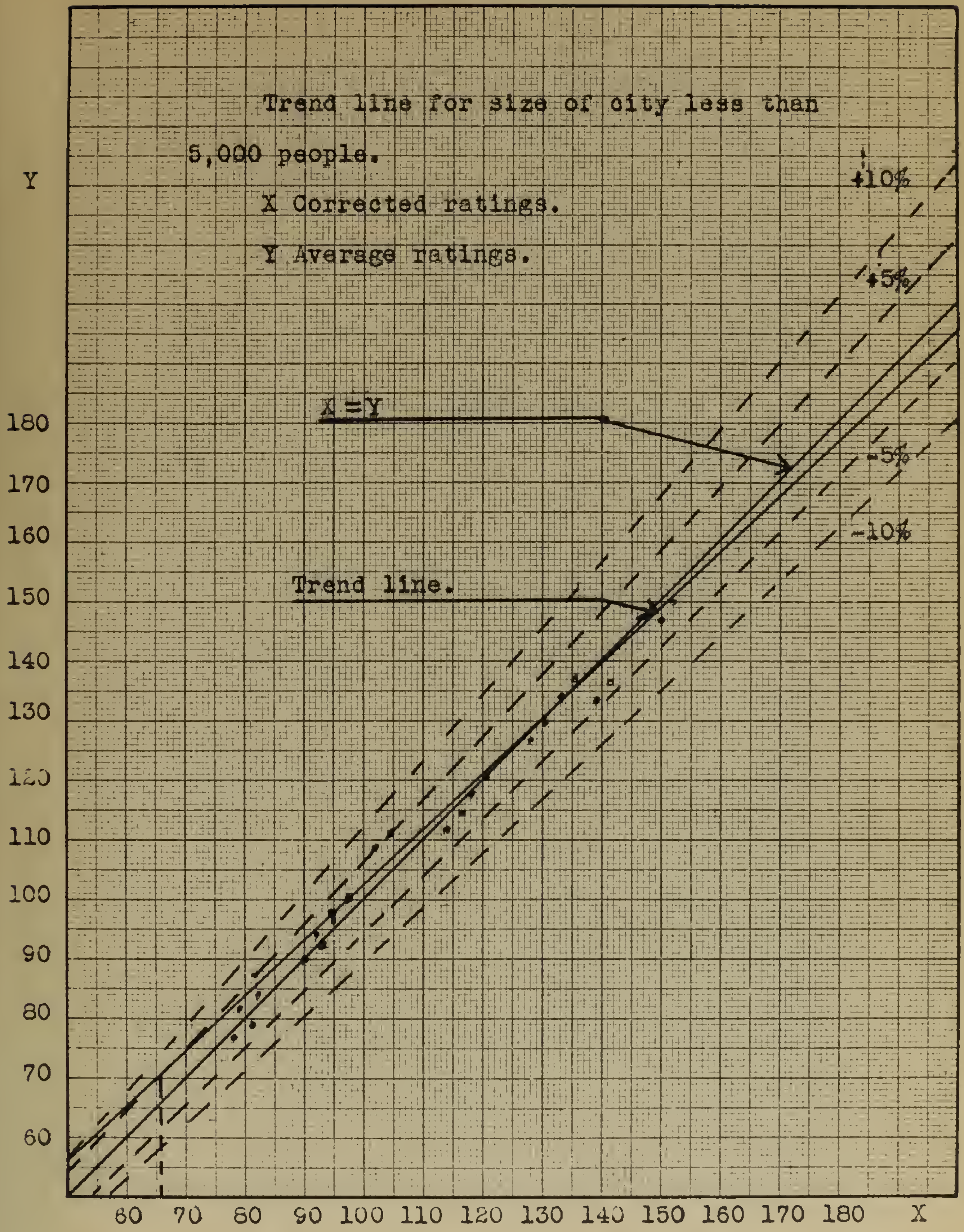

Trend line for size of city less than
5,000 people.
X Corrected ratings.
Y Average ratings.
X=Y
Trend line.
+10%
+5%
-5%
-10%
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 18

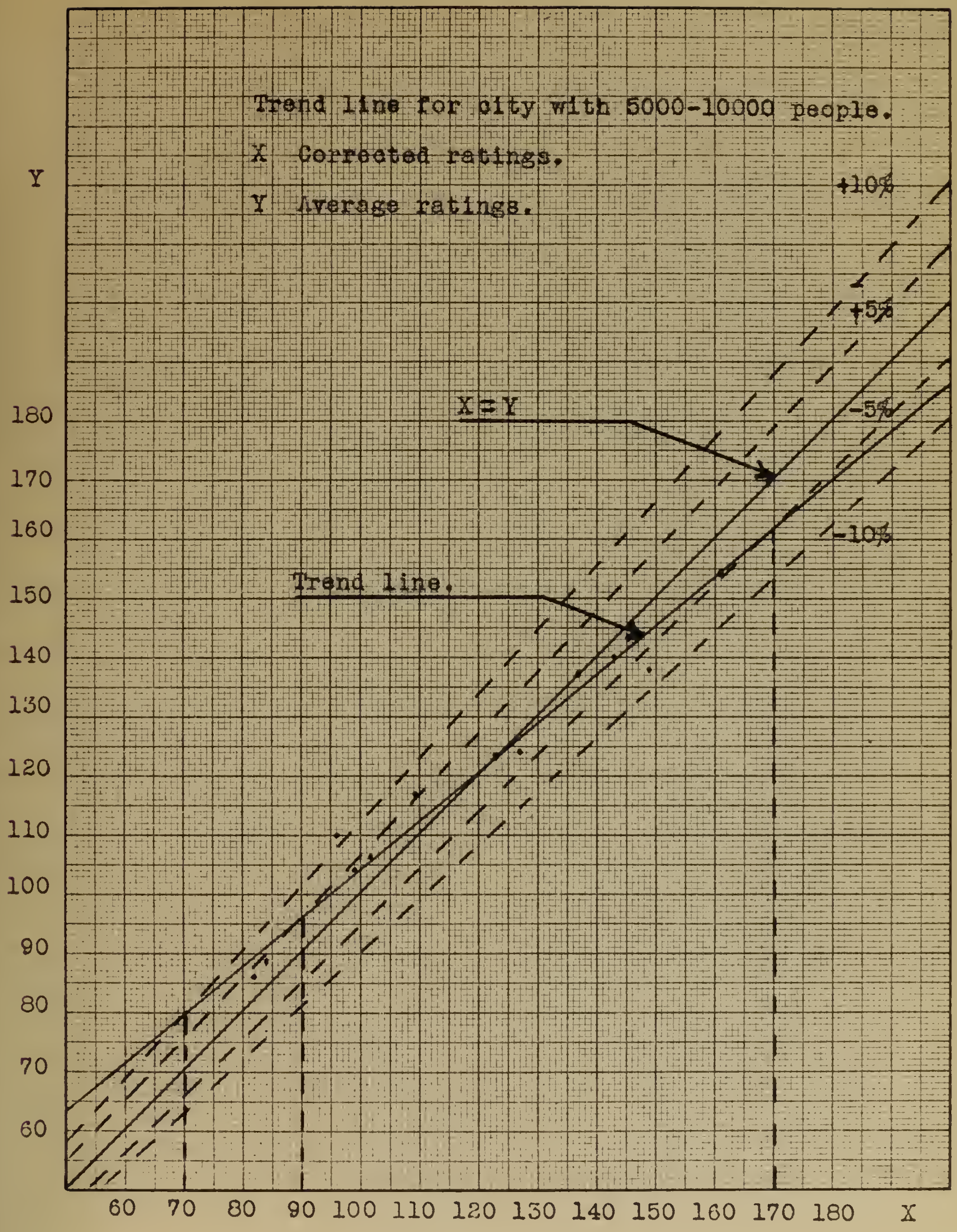

Trend line for city with 5000-10000 people.
X Corrected ratings.
Y Average ratings.
Y
+10%
+5%
-5%
-10%
X = Y
Trend line.
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 19

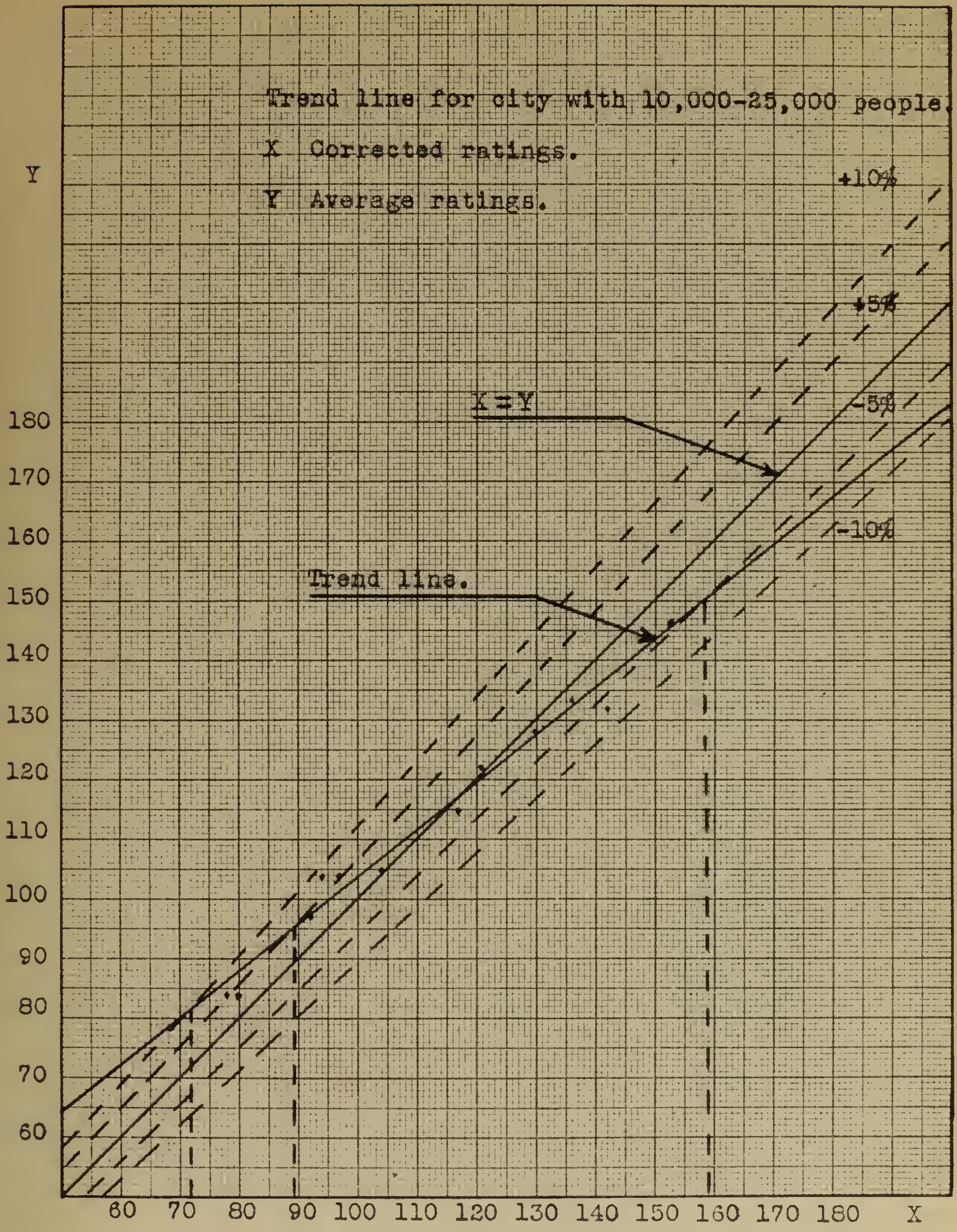
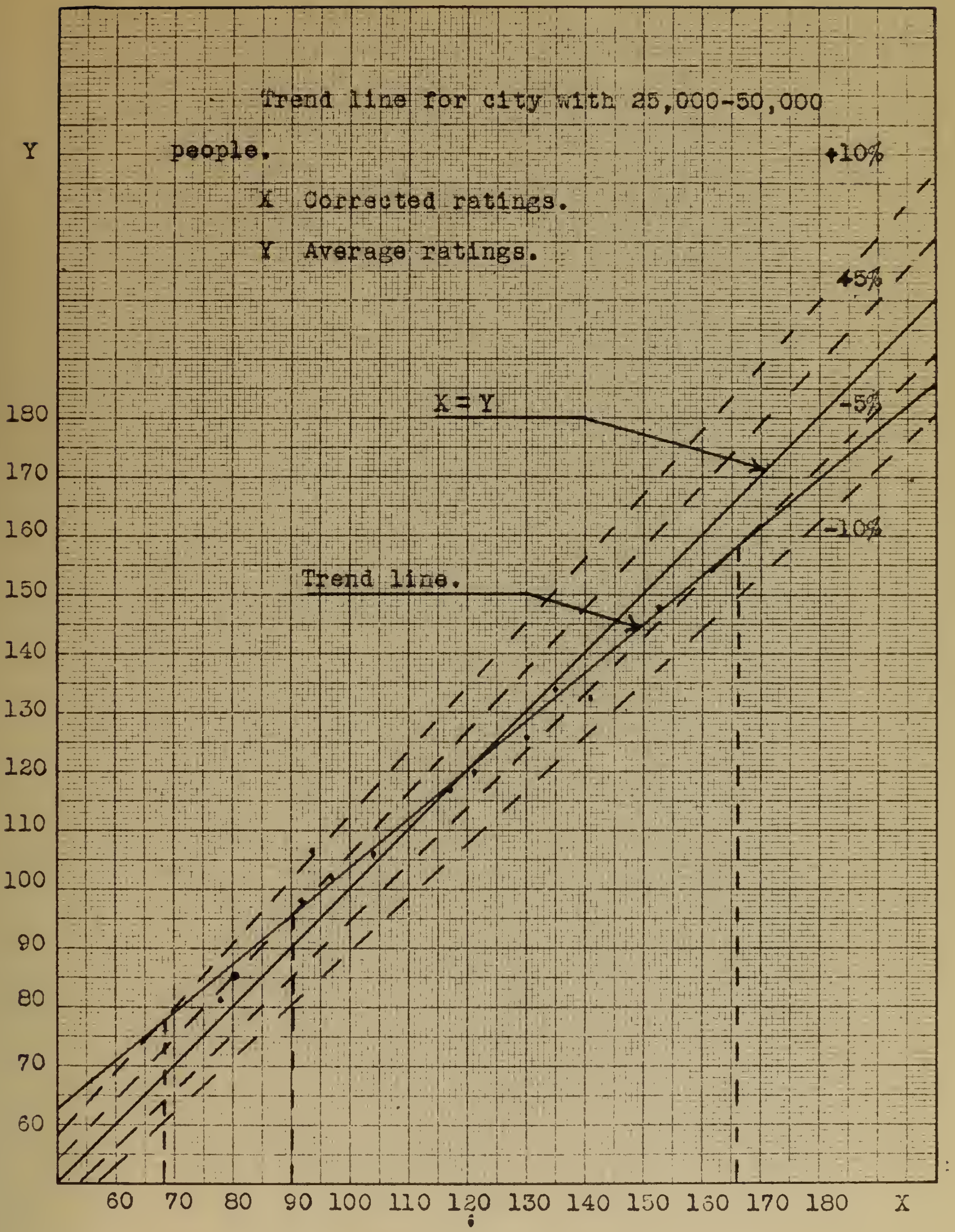

Trend line for city with 10,000-25,000 people.
X Corrected ratings.
Y Average ratings.
+10%
+5%
-5%
-10%
X = Y
Trend line.
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 20



Trend line for city with 25,000-50,000 people.
X Corrected ratings.
Y Average ratings.
Y
X
+10%
+5%
-5%
-10%
X = Y
Trend line.
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180

Fig. 21

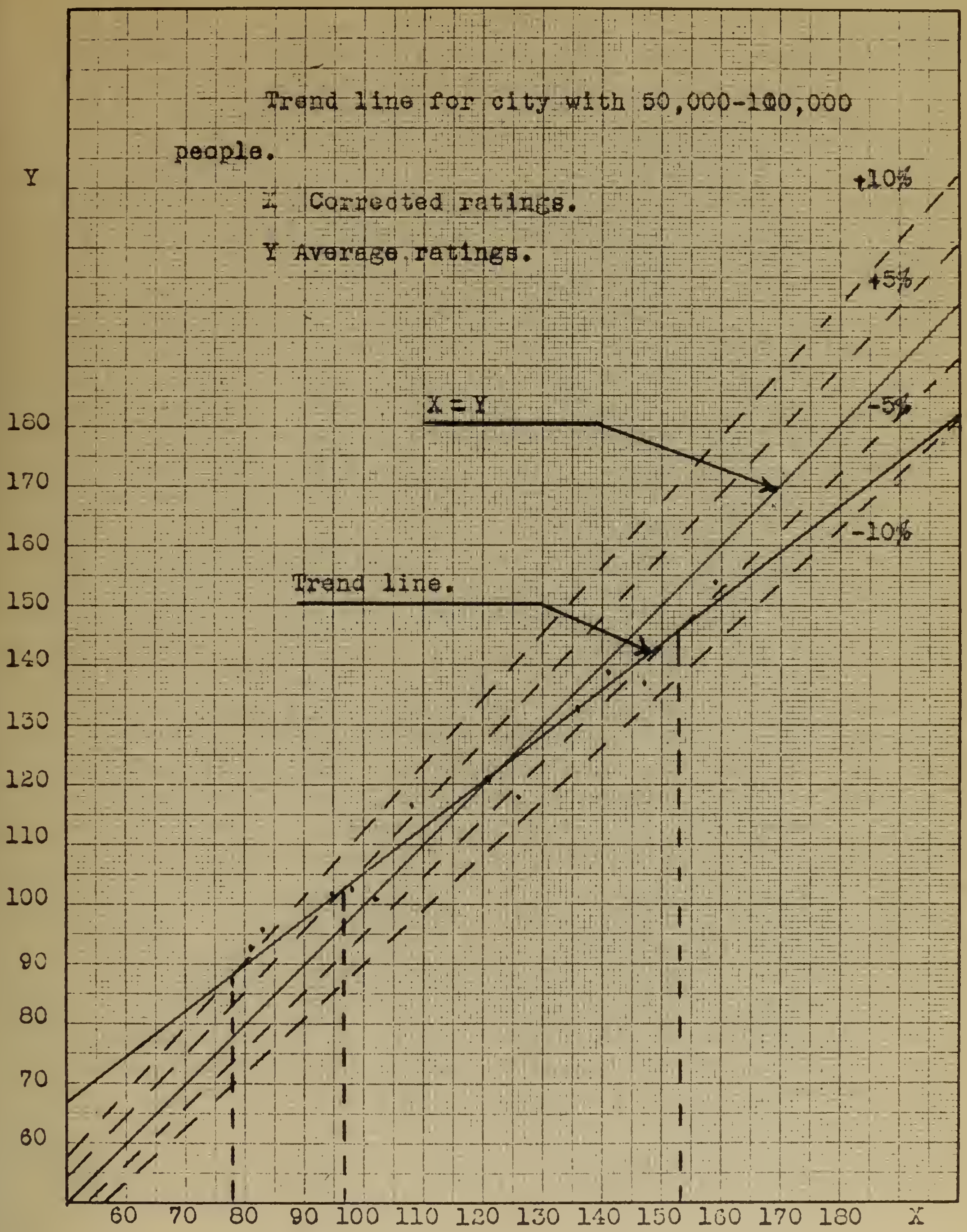

Trend line for city with 50,000-100,000 people.
X Corrected ratings.
Y Average ratings.
X = Y
Trend line.
+10%
+5%
-5%
-10%
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 22

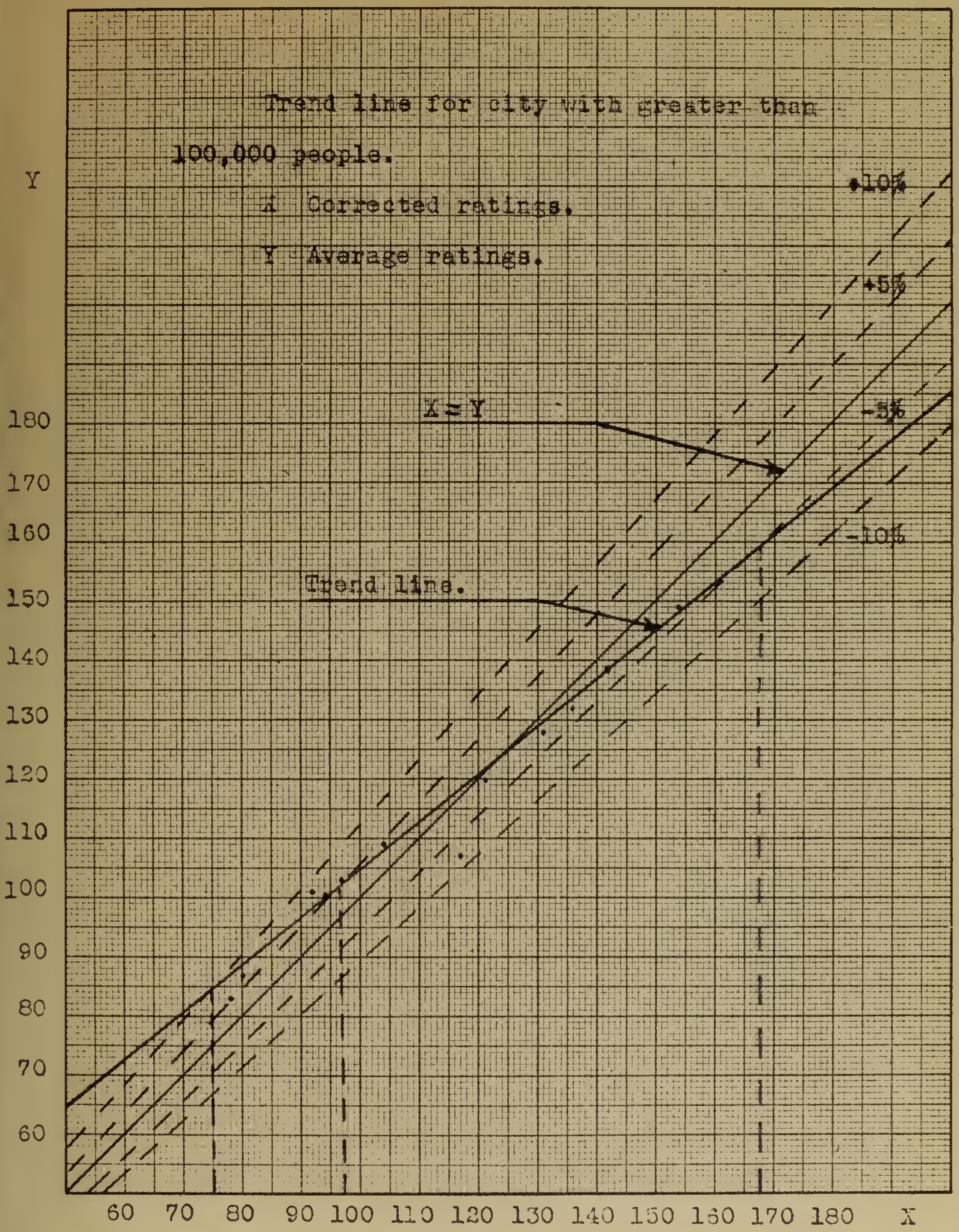

Trend line for city with greater than
100,000 people.
X Corrected ratings.
Y Average ratings.
+10%
+5%
-5%
-10%
X = Y
Trend line.
Y
180
170
160
150
140
130
120
110
100
90
80
70
60
60
70
80
90
100
110
120
130
140
150
160
170
180
X

Fig. 23

Job description

Left hand.	Right hand.
Transport empty to pins.	Hold scribe through entire cycle.
Grasp one pin.	
Transport loaded to scribe.	
Position and transport loaded past scribe.	
Transport loaded to pin release area.	
Position and release load.	

Job description of the synthetic task: scribe end of brass pins, using return chute.

APPENDIX B

MATHEMATICAL PROCEDURE

Mathematical procedures involved the computing of the true pace or "corrected rating" for each pace; the use of the "analysis-of-variance" technique, and fitting a line to a series of points by the method of "least squares". A short discussion on these procedures follow.

1. Computing the true pace or "corrected rating".

a. Designate "corrected rating" as X_n.

b. Obtain the average frame count per cycle for each pace. Designate the frame count as N_n.

c. To any one of the paces assign the value 100. Let this be pace number 10. Designate this as $X'_{10}=100$.

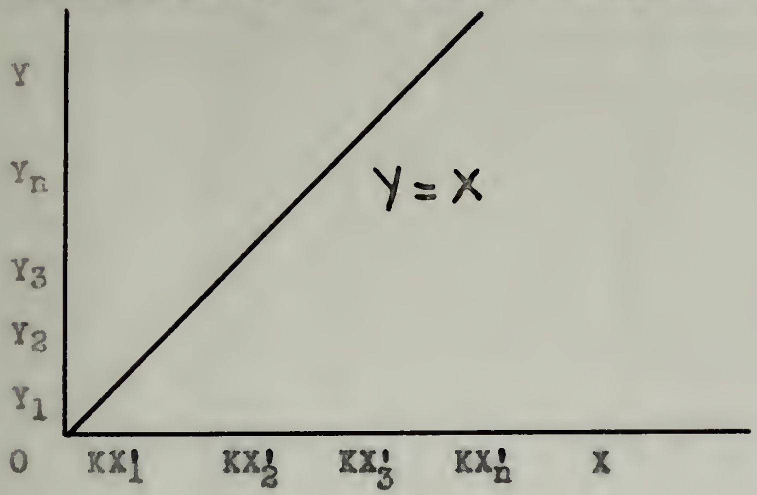
d. Since each pace bears a fixed relationship to all other paces, the relationship being the ratio of their respective frame counts, we have the equation $X'_n \times N_n = C$, a constant. We now find X'_n for each pace from this equation and $X'_{10}=100$.

e. The "corrected rating", X_n, bears the following relationship, $X_n = KX'_n$, where K is a constant. A formula for deriving K will be given in a subsequent paragraph.

f. With the value of K determined, compute X_n.

These values of X_n are in a direct ratio with each other according to their respective frame count per cycle, are related to the raters' average, and represent the nearest approach possible to a true rating.

Proof that $K = \dfrac{\sum_{n=1}^{\infty} X_n' Y_n}{\sum_{n=1}^{\infty} X_n'^2}$. This proof was derived by Dr. M. E. Mundel, Professor of Industrial Engineering, General Engineering Department, Purdue University.



Problem: To find the best set of X values about $Y = X$.

Given: $X_1, X_2, \ldots\ldots, X_n$, the corrected ratings for each pace.

$$X_1', X_2', \ldots\ldots, X_n' = \frac{C}{N_n'}.$$

$Y_1, Y_2, \ldots\ldots, Y_n$, the average of the raters' estimate for each pace.

K is a constant to be selected such that $\sum d^2$ equals a minimum, where d is the variation about the line $Y = X$.

Proof: $\sum d = (Y_1 - KX_1') + (Y_2 - KX_2') + \ldots + (Y_n - KX_n')$.

$$\sum d^2 = Y_1^2 - 2KX_1'Y_1 + K^2X_1'^2 + \ldots + (Y_n - KX_n')^2.$$

The value of K which will permit $\sum d^2$ to be a minimum is obtained by setting the partial derivative of $\sum d^2$ with

respect to K equal to 0 and solving for K.

$$\frac{\partial \sum d^2}{\partial K} = -2K_1'Y_1 \ + \ 2KX_1'^2 - \ \ldots . \ - \ 2X_n'Y_n + 2KX_n'^2 = 0.$$

Solving for K we have,

$$K = \frac{X'Y_1 + X_2'Y_2 + \ldots + X_n'Y_n}{X_1'^2 + X_2'^2 + \ldots + X_n'^2}.$$

$$K = \frac{\sum_{n=1}^{\infty} X_n'Y_n}{\sum_{n=1}^{\infty} X_n'^2} .$$

2. Analysis-of-variance technique.

Details of the analysis-of-variance tests are not presented here[10] but it can be shown that if we have the variable X arranged in the following manner,

$$\begin{array}{|cccccccc|c}
\hline
X_{11} & X_{12} & \ldots & X_{1j} & \ldots & \ldots & X_{1b} & & \bar{X}_{1.} \\
X_{21} & X_{22} & \ldots & X_{3j} & \ldots & \ldots & X_{2b} & & \bar{X}_{2.} \\
\vdots & \vdots & & \vdots & & & \vdots & & \vdots \\
X_{i1} & X_{i2} & \ldots & X_{ij} & \ldots & \ldots & X_{ib} & & \bar{X}_{i.} \\
\vdots & \vdots & & \vdots & & & \vdots & & \vdots \\
X_{a1} & X_{a2} & \ldots & X_{aj} & \ldots & \ldots & X_{ab} & & \bar{X}_{a.} \\
\hline
\bar{X}_{.1} & \bar{X}_{.2} & \ldots & \bar{X}_{.j} & \ldots & \ldots & \bar{X}_{.b} & & \bar{X}
\end{array}$$

and if we assume these values of X are random sample values from a normal population with mean m and variation $\sigma,^2$

---

[10] Paul G. Hoel, *Introduction to Mathematical Statistics*, p. 154-161, John Wiley & Sons, Inc., New York, 1949.

$$\text{then } F_c = \frac{a \sum_{j=1}^{b} (\bar{X}_{.j} - \bar{X})^2 \quad (a-1)\ (b-1)}{\sum_{i=1}^{a} \sum_{j=1}^{b} (X_{ij} - \bar{X}_{i.} - \bar{X}_{:j} + \bar{X})^2 \ (b-1)}.$$

The numerator, with (b-1) degrees of freedom, measures variation between columns. The denominator, with (a-1)(b-1) degrees of freedom, measures the "experimental error", that is, variation in the fundamental variable after row and column effects have been eliminated.

In this thesis, a is the number of paces, b is the number of breakdowns, X is the percentage of raters within ±5% of the corrected rating or any designated level of accuracy.

F_c was computed at the ±5% and ±10% levels of accuracy for each category of breakdown and was compared with the tabular value of F at the 5% level of significance.

3. Fitting a curve to a set of points by the method of "least squares".

Details of the method of "least squares" will not be presented here but involves the use of the following equations.[11]

$$\sum Y = aN + m \sum X.$$

$$\sum XY = a \sum X + m \sum X^2.$$

a = intercept, m = slope.

With the values of a and m determined we substitute them in the general equation for a straight line, $Y = mX + a$, and obtain the line best fitting the available points.

---

[11] Ibid., p. 79.

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